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The
Economy
# of the
Animal Kingdom

CONSIDERED
ANATOMICALLY, PHYSICALLY AND PHILOSOPHICALLY

BY

EMANUEL SWEDENBORG

TRANSACTION III

The Medullary Fibre of the Brain and the Nerve Fibre of the Body

The Arachnoid Tunic

Diseases of the Fibre

TRANSLATED FROM THE LATIN AND EDITED BY

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PHILADELPHIA, PA.
1918

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Preface.

The translation here offered to the reader first appeared in the pages of the New Philosophy, the official organ of the Swedenborg Scientific Association, from October, 1909, to October, 1915. It is now reprinted with additions, corrections and indices.

The Latin original is contained in codex 74 of the Swedenborg manuscripts preserved in the library of the Royal Swedish Academy of Sciences at Stockholm. This codex contains several distinct treatises with independent paging and in the following order:

1. The Fibre, pp. 65-433 (*unfinished*).
2. The Red Blood, 24 pp.
3. The Animal Spirit, 24 pp.
4. Sensation, 13 pp., followed by 3 blank pages (*unfinished*).
5. Origin of Soul, 8 pp.
6. Action, 32 pp.
7. Harmony of Soul and Body, 80 pp. of which 2, in one place, and 32 in another, are missing (*unfinished*).

Although now bound in a single manuscript volume, it would seem that these seven works were not originally contained in one volume. This is indicated by the independent pagination, and, more clearly, by the fact that in the original catalogue of Swedenborg's manuscripts, prepared by his heirs in 1772, shortly after his decease, specific mention is made only of nos. 3, 4, and 6, which are listed as "three short transactions" on the Animal Spirit, Sensation and Action (3 *Documents Conc. Swedenborg,* 784). The other works, nos. 1, 2, 5, and 7, seem, in this catalogue, to be included under the heading "Several larger and smaller fragments" on physiological subjects (*ibid.* 784-5). The separate works were, however, bound together as early as 1787; for in the official catalogue prepared for the Royal Academy in that year, they are listed as "Codex 74. Anatomical and Physiological matters" (*ibid.* 796). No further indication of the contents of this codex is given; nor does the volume appear to have received any detailed examination, until sixty years later, when, in 1843, DR. SVEDBOM, the librarian of the ROYAL ACADEMY, acting at the instance of DR. J. J. GARTH WILKINSON, examined the codex and gave some description of its contents (*Animal Kingdom*, 654, 657).

Following this examination, the SWEDENBORG SOCIETY,—a body which had been recently instituted for the purpose of publishing the philosophical works of Swedenborg,—applied to the ROYAL ACADEMY for the loan of the codex with a view to its publication; and, in testimony of the high esteem in which the official New Church was regarded by the ROYAL ACADEMY, the request was generously granted.

The manuscript was entrusted to DR. WILKINSON, as editor. Under his care its six smaller treatises, together with two or three other little works, were published by the SWEDENBORG SOCIETY in the autumn of 1846 under the title OPUSCULA QUAEDAM ARGUMENTI PHILOSOPHICI. In the same year the Society also published an English translation of this volume by Dr. Wilkinson.

The work on THE FIBRE was published in the following year, 1847, as a separate volume, but was not followed by an English translation. Soon after the appearance of the Latin edition, however, translations of short passages were printed in the periodicals of the New Church, as follows:

Nos. 158-9, 370-9, 370-394, translated by the Rev. J. H. Smithson; and nos. 421-432 translated by John Bogg, M. D., in INTELLECTUAL REPOSITORY, London, 1847, pp. 393-4; 1848, pp. 27-31; 1852, pp. 303-7, 345-6, 352-8; 1848, pp. 298-303.

Nos. 285-291, 486-8, 520 translated by ELIHU RICH in NEW CHURCH QUARTERLY, London, 1848, pp. 21-3, 28-9, 31-2.

Nos. 421-432, translated by PROF. GEORGE BUSH in NEW CHURCH REPOSITORY, New York, 1849, pp. 81-7.

No further translations appeared in print until 1882, when Nos. 340-1 and 343 were included by DR. R. L. TAFEL in his translation of THE BRAIN (pp. 423-4). Fifteen years later a translation, by CHARLES L. OLDS, M. D., of the whole of Part III. on DISEASES OF THE FIBRE, was printed in NEW CHURCH LIFE (Philadelphia) for 1897-1899.

In addition to these printed translations, the writer has also had access to two manuscript translations,—the one, by BISHOP W. F. PENDLETON, covering,—with some short omissions,—the whole of Part I. ON THE FIBRE; and the other, by PROF. CAMILLE VINET, covering the whole of Part II. ON THE ARACHNOID TUNIC.

All these translations have been carefully consulted in producing the present work, and the writer gratefully acknowledges both the direct help and the many valuable suggestions which he has derived from the work of his predecessors.

In preparing the work for the press, the translator has supplied the first fifty-six paragraphs, which are missing from the original manuscript, but which clearly consisted of quotations from anatomical authors. At the commencement of the early chapters, he has also added certain introductory paragraphs wherein the broken parts of the author's inductions, are gathered together into one. But we shall again refer to these two points later on in this Preface.

All the citations and quotations made by the author have been verified by reference to the original works, and where any change was required this has been noted either in a footnote, or by the use of brackets. The plates from LEEUWENHOEK's works have been included in the volume,—as they were also included in many of the copies of the Latin edition. It would appear to have been the author's intention to have printed these plates when publishing his work, and, in any case, he certainly intended that they should be frequently consulted by the reader.

Two Indices have been prepared. The first is an index of authors cited,—in which are included Swedenborg's references to his own works, both published and prospective. The other is an Index of Subjects; this has been so prepared as to serve the purpose of a digest as well as of an index,—but we explain this more fully in our note prefixed to the Index itself.

Two Lists of Corrigenda have been prepared,—one of the Latin text, and the other of the English translation. By the kindness of MR. ALFRED H. STROH, all the Latin corrections have been compared with the original manuscript, and the result of the comparison is duly noted.

The corrections to the English text are very numerous; this is owing to the fact that a great number of them are based on our restoration of the first fifty-seven paragraphs of the work,—a restoration which we were unable to bring to completion until the translation was already in print.

* * * *

We turn now to a consideration of the place which THE FIBRE holds in the cycle of the author's physiological and psychological writings, and to some consideration of the manuscript.

The work on THE FIBRE is undoubtedly a part of that series of "Physiological Transactions," volumes I. and II., of which were published by the author under the title, ECONOMY OF THE ANIMAL KINGDOM.

What appears to be the first draft of the commencement of this series is contained in codex 65 of the Swedenborg MSS.; indeed, in a subsequent and, as yet, unpublished manuscript on the Brain (Codex 58) the author specifically refers to this codex 65 as his "first projection" (*Photolithographed MSS.*, 62).

Codex 65 contains "Transactions" I., II. and III. Originally the manuscript consisted of 1,482 pages, but as now preserved it contains only 1,098 pages, nearly all the missing pages being from Transactions I. and II. The larger part of the manuscript is reproduced in Vol. IV. of the PHOTOLITHOGRAPHED MSS., edited by DR. R. L. TAFEL. From its contents, which include several references to a proposed Transactions IV, it can be shown that the author's first plan for his series of Transactions was as follows:

Trans. I. The Cortex, Medulla and Vessels of the Brain. Degrees as exhibited in the Cortical Gland.
Trans. II. The Coverings of the Brain; its Animation, Determinations and Functions.
Trans. III. Introduction on the Animal Spirit; to be followed by a detailed examination of the various members of the Cerebrum.

Trans. IV. The Composition of the Blood (4 *Photolith.*, 762, 793, 801); and, at the end, the Dependance of Muscular Action on the Animation of the Brain (*ibid.* 522).

PLAN OF THE "ECONOMY" SERIES.

This plan was, however, modified by the author when he commenced the publication of his Physiological Transactions under the title Economy of the Animal Kingdom. The first volume of this work was published in 1740 as "Transaction I. On the Blood," etc., with a concluding chapter, entitled "Introduction to Rational Psychology." The second volume was published in 1741, as "Transaction II.," On the Motion of the Brain; the Cortex; and the Human Soul.

Comparison of these published Transactions with the Transactions of the first projection in codex 65 shows that the last chapter of Transaction I. of the Economy (Introduction to Rational Psychology) covers much of the same ground as is covered in Transaction II. of codex 65; and that Transaction II. of the Economy covers much of the ground covered in Transactions I. and II. of the same codex; indeed in several cases the same anatomical quotations are used. We are thus led to conclude with some degree of certainty, that Transactions I. and II. of codex 65 are a first draft or first projection of what was subsequently published as the Introduction to Rational Psychology, in Transaction I., and the whole of Transaction II. of the Economy of the Animal Kingdom.

From various references made by the author in this latter work to Transactions which are to follow, it can be established that, at the time of its publication, his plan for the whole series of Transactions was as follows:—the references are to the Economy:

Trans. I. The Blood and Blood Vessels. Introduction to Rational Psychology.
Trans. II. The Motion of the Brain. The Cortex. The Human Soul.
Trans. III. The Cortical and Medullary substance of the Brain (I, 147, 157; II, 146, 115, 117). The Construction of the Fibre (II, 122). The Animal Spirit and its

course through the Fibre (II, 127). The Arachnoidal Humors (II, 130).

Trans. IV-VI. The Brain (I, 157; II, 115, 130, 146, 305); the Birth of the Animal Spirit (II, 130).

Trans. VII. The Tongue, Trachea and Lungs (I, 50, 279).

Transactions on the Liver (I, 343). Generation, (II, 295). The Muscles (I, 129, 142, 557). Freewill (II, 261, 299). Souls of Men and Brutes (II, 259). Harmony (I, 155).

The guiding principle that appears to have ruled in the formulation of the above plan whereby the human soul was to be sought in the body, is, that the universals of the body were to be treated of first, and then its various parts were to be taken up and examined in detail.

The same principle of treatment is seen in the first projection contained in codex 65; but in the Economy the application of this principle is changed, as may be seen from the following table:

Codex 65.	The Economy.
1. The universals of the Brain, *i. e.,* its Degrees, Motion, Function; the Animal Spirit. (*Trans.* I. and II.)	1. The universals of the Body, *i. e.,* its Blood and Vessels; the Heart. Introduction to Rational Psychology. (*Trans.* I.)
2. The Animal Spirit. The members of the Cerebrum. (*Trans.* III.)	2. The Universals of the Brain, *i. e.,* its motion and Cortex. The Soul. (*Trans.* II.)
3. The universals of the Body, *i. e.,* the Blood; the influence of the Brain's Animation on the Body. (*Trans.* IV.)	3. The universals of the influx of Brain into Body, *i. e.,* the Fibre and its Spirit. (*Trans.* III.)
4. *seq.* The various parts of the Body. (*Trans.* V. *seq.*)	4. The members of the Brain. (*Trans.* IV.-VI.)
	5. The parts of the Body. (*Trans.* VII. *seq.*)

From this Table it will be seen that the first plan, or that of codex 65, was so far modified in the Economy that, instead of treating first of the brain and then of the body, the author planned to devote his first Parts or Transactions to the universals entering into the entire series of physiological investigations, and then to take up the members of the brain and afterwards the members of the body.

THE PURPOSE OF THE "ECONOMY" SERIES.

In this plan we find Swedenborg's characteristic and eminently rational use of the two methods of investigation,—the analytical and the synthetic. It is true, as he frequently points out, that human beings of our age must first ascend by the analytical way,—the way of experimental facts analytically investigated,—before they are prepared to descend by the synthetic way,—the way pointed out by ascertained and established doctrines. But by this, Swedenborg clearly did not mean that it behooved him to lay before his reader every detail of the subject under investigation, and to derive no conclusions except as explicitly based on the exhaustive examination of these details. This is the method of the learned of to-day. But with Swedenborg the analytical method was used for the purpose of thereby arriving at those universal principles and doctrines, in the light of which alone can there be any comprehension of the multitudinous details of the brain and body, and of the many problems which they present for solution. The analytical method was to be used, not for the purpose of solving particular and subordinate problems, but for the purpose of arriving at universal doctrines; and the subjects of the first analytical investigation were to be, not any specific parts of the human brain or body, but that brain and body considered as a whole. Thus the searcher after truth can receive those universal doctrines which are the principles of Nature herself, and by the guiding thread whereof he can safely tread the labyrinthine paths of science, to behold at every step the Wisdom of the Creator.

There is abundant evidence that, before SWEDENBORG published the ECONOMY, he had made the most thorough investigation into the anatomy of the brain and body; and that he had added to his knowledge by himself entering upon the work of dissection (*E. A. K.* 401, 403, 485). For the purpose of investigating the human soul (he says) "I have diligently examined the anatomy of the body, and especially the human body with unwearying labors and intense study; and I have examined its several parts with the same industry as I have here employed on the cortical substance" (*2 E. A. K.* 214). But all this industry was expended with the single purpose of seeking out those universal laws from which Nature acts, and in the light of which, when once discovered, the search into the parts of the human body can be taken up anew as a means for the discovery of the soul in the temple wherein she dwells.

It was in accordance with this plan that SWEDENBORG commenced the publication of his series of physiological works. In the early works of the series the reader was first to be led by the analytical method to a comprehension of certain universals in the human body before being invited to the study of its particular members and viscera. Hence the ECONOMY commences with the blood,—the corporeal soul and universal essence of its body. Then follows the doctrine of Order, Series and Degrees, laid down in the Introduction to Rational Psychology. After this comes Transaction II. on the Cortex of the Brain, and its Motion,—these being the great universals which must rule in every study of the brain. Next was to follow Transaction III. on the Fibre and Animal Spirit,—these being the universal means whereby the soul and mind manifest their presence and operation in the body. After these universal studies the series was to be continued by special Transactions on the Brain, the Abdominal and Thoracic viscera, the Organs of Generation, and, finally, the Soul.

After publishing the second of these Transactions in 1741, Swedenborg published no further work until 1744 when his ANIMAL KINGDOM appeared, wherein he appears to lay down an entirely new plan for his physiological series. The new series was to consist of seventeen "Parts," which, commencing with the viscera of the body, were to take up in succession the heart and blood, the organs of generation and of the five senses, the brain and its diseases, the doctrines of form, order, correspondence, etc., and, finally, the human animus, mind and soul.

THE "ECONOMY" AND THE "ANIMAL KINGDOM."

It has been supposed that in commencing this new series Swedenborg discards his former plan, begun in the ECONOMY, as unsatisfactory. But this conclusion is not warranted by the facts. It is true that, in this new series, SWEDENBORG somewhat changed or modified the order in which his studies were to be laid before the public; but there was no essential change. The ANIMAL KINGDOM is, in fact, a continuation of the ECONOMY, and this along the same general lines. The published Transactions of the latter work had prepared the ground by laying down, on an analytical foundation, certain universal principles. This being accomplished, the next step was the examination of the various parts of the body and brain; then the gathering together in orderly presentation of the new doctrines discovered; and, finally, the revelation, the unveiling, of the soul. This intimate connection between the ECONOMY and the ANIMAL KINGDOM is involved in the following statement in the latter work:

> "Not very long ago I committed to the public press the ECONOMY OF THE ANIMAL KINGDOM,—a work which was divided into Transactions,—but only the Transactions on the Blood, its Arteries and Heart, and on the Motion and Cortex of the brain; and, before the several stages of the journey had been run, I made a rapid passage to the soul. But on deeper reflection I found that I had taken my steps more hastily and quickly than was due, that is to say, merely on the basis of an investigation of the blood and its proper organs,—which was done because I was impelled by the ardor of learning. But since the soul acts in supremes and inmosts, and does not come to view until all her swathings have been unwrapped in order, therefore I have determined to allow myself no rest until I have run through the whole field even to the goal." (*A. K.* 19.)

The passage to the soul had been "too hasty;" and yet in this passage,—we refer to the last chapter of Transaction II. of the ECONOMY,—Swedenborg lays down the great universal doctrines concerning the human soul to which he constantly refers in his later works belonging to the Animal Kingdom series, and from which he never in the least deviates. And yet the passage had been "too hasty." It is not enough to view the soul merely on the basis of the universals of the body and brain; but, having thus been given a view of the soul in her universal operations, it is now necessary that we descend again to the body and traverse the whole field of anatomy in order that the soul may be fully revealed to our reverent and newly awakened gaze. This, indeed, had been the plan of the ECONOMY; but the plan had not been publicly set forth, and the work remained apparently unfinished and abandoned,—as a too hasty passage to the soul. Its use, however, had been served,—it had furnished the light to guide the steps in the "several stages" of the long journey that had yet to be run.

As contemplated in the published Transactions of the ECONOMY, the three Transactions on universals,—the Blood, the Brain, and the Fibre,—were to be followed by detailed studies of particular parts of the body. First was to be taken up the members of the brain, then the viscera of the abdomen and thorax, the organs of generation, etc. In the ANIMAL KINGDOM series the order in pursuing this detailed investigation is changed, but the characteristic quality of the studies to be now commenced, remains the same; that is to say, the series initiated by the first Transactions of the ECONOMY is now to continue with the analytical investigation of the parts of the human body.

And here we see the reason for the change in title from the "Economy of the Animal Kingdom, considered anatomically, physically and philosophically" to "The Animal Kingdom considered anatomically, physically and philosophically." The former work, dealing with the universals of the body—the blood and cortex, together with the doctrine of degrees, and a universal view of the soul—is called THE ECONOMY (*i. e.*, the government) OF THE ANIMAL KINGDOM. But the latter, wherein Swedenborg, from the light of these universals, enters upon the particular study of the parts of brain and body, receives a new name, THE ANIMAL KINGDOM. In both series the subject is "considered anatomically, physically and philosophically."

From a passage in the ECONOMY, it might appear that SWEDENBORG intended to incorporate some part of his ECONOMY into the ANIMAL KINGDOM; for, in the latter work, speaking of the analysis of the blood, he says: "I have, indeed, made this analysis in the ECONOMY OF THE ANIMAL KINGDOM, but it must be inserted in the present work in its proper place" *i. e.*, as Part III. (*A. K.* 217d). Other references, however, show that the Part III. of the ANIMAL KINGDOM on the Heart and blood, was to be quite distinct from the former treatise; for very frequently reference is made to the treatment of the blood in the ECONOMY, and, ***at the same time,*** to Part III., where the subject of the blood will be further treated of (124a, 258i). Hence the "it" in the quotation just made, refers, not to the ECONOMY, but to another "analysis of the blood."

But when Part III. became due in the series it was omitted, the omission being explained by the author in the following words which are written at the commencement of Part III., as published, but which, according to the original plan, was to have been Part VI.:

> In the index of the series of the whole work the promise was given that we would next (*i. e.*, after Part II.) treat of the Heart, its arteries, veins and blood; and also of the Members of Generation. . . . But the heart and its vessels and blood has already been treated of in our ECONOMY OF THE ANIMAL KINGDOM. As to the members of generation, they must be treated of after we have learned what the animal spirit is and what the soul, for it is by these organs that the soul comes off from itself into the offspring. It would therefore be premature, and so I myself would be unequal to the task, to deliver anything concerning these members as instrumental causes, without a knowledge of the principal cause. I have therefore considered that we must first ascend by degrees to the supreme sphere, from whence we may legitimately deduce the principles of things, and where we may speak of the soul with greater certainty and definiteness." (*A. K.* 407.)

The reason here given for omitting Part III. on the Heart, is that it has already been treated of in a former work; but elsewhere our author plainly intimates that this Part is omitted also for the same reason as that given for the omission of the Part on Generation, namely, that further universals must be learned before the enquiry can be further prosecuted. The passage to which we refer occurs in the first draft of Part VI. of the Animal Kingdom, On the Senses, and reads as follows:

> We have promised we would next treat of the heart, arteries, and blood; and then of the members of generation; but, further than what has been said of the heart, arteries and blood in the work which I have called Economy of the Animal Kingdom,—the matter being more deeply reflected on,—it is not allowed to advance our steps immediately and next in order. For we learn what the blood is from all things of the body. All the nooks and crannies through which it runs must first be investigated, namely, the viscera of the abdomen and thorax, and especially the brain. (*Senses* 6.)

It is clear, therefore, that when Swedenborg was publishing the Animal Kingdom it was his intention to supplement Transaction I. of the Economy by another treatise on the blood, which should constitute Part III. of the Animal Kingdom; but that when he had finished Part II. he concluded to rest content with the presentation of the blood and the heart as given in the Economy, reserving to himself the right of going more fully into these studies in the light of his further investigations into the human body.

But, in any case, his general plan stands forth clearly, that universals must first be treated of: First, The Blood, and the doctrine of Series and Degrees. Second, The Cortex and Its Motion; the spirituous Fluid and the Soul. Third, The Fibre and Animal Spirit, as the connecting link between brain and body; and the Doctrine of Forms as the key to the laws of ascent and descent. It was after these had been presented that Swedenborg proposed to enter upon the particular investigation of the body and brain. The plan is the same in both the Economy (as projected) and the Animal Kingdom; it was only the method of carrying it out that was modified. This may be seen from the following table setting forth the two series:

Economy Series.	Animal Kingdom Series.
1. The three universals. (*Trans.* I.-III.)	1. The two universals as given in the published Economy.

2. The brain. (*Tr.* IV.-VI.)	2. The body, beginning with the mouth and tongue, and including the organs of generation and sensation. (Parts I.-VI.)
3. The body, beginning with the mouth and tongue; generation, etc. (*Tr.* VII. *seq.*)	3. The brain and the fibre. (Parts VII.-XI.)
4. The soul.	4. The soul. (Parts XII.-XVII.)

CONTINUATIONS OF THE "ECONOMY."

Only two of the proposed three universals are dealt with in the published Transactions of the ECONOMY. But it is clear that the author had the distinct intention of following these published Transactions by a third to treat of the Fibre. This is shown by the numerous references (noted above) in the ECONOMY itself to a proposed Transaction III on the Fibre and Animal Spirit; and it is rendered doubly certain by an advertisement contained in the second edition of the ECONOMY published by the author in 1742. With the exception of the title page and this advertisement, this second edition is word for word the same as the first, and it is quite evidently merely a re-issue of the printed sheets of the first edition with a new title page and a page of advertisement, and another of *Emendanda*.

The advertisement is entitled "Catalogue of books published and to be published." After enumerating the PRINCIPIA and other works already published, the Catalogue continues:

FOUR BOOKS SOON TO BE PUBLISHED.

1. The Medullary Fibre of the Brain and the Nerve Fibre of the Body.
2. The Animal Spirit.
3. Concordance of Systems on the Human Soul and its intercourse with the Body.
4. Divine Prudence, Predestination, Fate, Fortune and Human Prudence.

The announcement that these works are "soon to be published" justifies us in concluding that at this time, 1742, they were well in hand; otherwise the list might have been much extended, since the published Transactions of the ECONOMY mention many other works as a continuation of the series there commenced. But, in addition, the conclusion is supported by direct evidence, in that, among the author's MSS., are found two of the above works both of which are in form prepared for the press. The one is the present work on the FIBRE, and the other is the work on the HUMAN SOUL.

The manuscript on the SOUL is contained in codex 74, being the last of the seven works contained in that manuscript, as noted above at the commencement of this Preface. It did not, however, form a part of this codex at the time it was written, for its pages are of a different size than the pages of the rest of the codex. Originally it appears to have been a not inconsiderable work; but, at least, one-half of the original manuscript is lost. As now preserved it reaches to page 80, though of these 80 pages two are blank and 34 are missing. Moreover, the manuscript ends in the middle of a sentence, and an examination of its contents and their scope makes it clear that there were a large number of pages following page 80. That this work is the one referred to in the above list as "3. Concordance of Systems," etc., is indicated by its contents; for it at once enters into a discussion of the various systems that have been propounded respecting the harmony of soul and body. And that it was prepared for the press, is clear from its finished style and from the circumstance that it is preceded by a Preface to the reader. In this connection, it is also worthy of note that in this Preface the author explains that instead of following his original intention "to comprise in a single volume" his "long meditations on the soul and body," he had "thought it most prudent to divide the labor" and to issue five or six publications a year under the general heading "Psychological Transactions" (*Opus. Phil.*, p. 91-2). From which it would appear that it had been SWEDENBORG's intention to write further on the soul before commencing the particular transactions on the brain and body, which were originally to follow the transaction on the Fibre.

The author has also left a manuscript on the Animal Spirit. It comprises 24 pages and is bound in with the FIBRE in codex 74, though, as we have already noted, it was not originally a part of this codex. Whether it is the work referred to in the List of books to be published is not certain; its style, however, clearly indicates that it is not prepared for the press.

Number 4, of the List, the work on Divine Prudence, etc., is lost without any trace as to its whereabouts. That SWEDENBORG actually wrote the work is, however, explicitly stated by the author himself in his posthumous work on THE SOUL (n. 56). Possibly it formed a part of the manuscript containing the work on the Concordance of Systems on the Human Soul, and was lost, together with the latter part of that work.

THE FIBRE.

We turn now to the first work in the list of books to be published, namely, THE FIBRE. This is the work which is now presented to the reader. It forms by far the largest part of codex 74, as we have already noted. Its finished style and careful arrangement clearly indicate that it was prepared for the press, and there can be no doubt but that it is the work referred to in 1742 as "soon to be published." Consequently it was written between 1741, the date of the first edition of the ECONOMY, and 1742, the date of the second edition containing the advertisement of its publication in the near future. We may, therefore, fix the time of its composition, or, at any rate, of its preparation for the press, as the latter part of 1741 or the beginning of 1742.

As now preserved it is not complete; for it lacks both beginning and end. The first page of the manuscript has, at the head of the page, the title DE FIBRA; after this comes the work itself, commencing with paragraph 58. In the right hand upper corner, the page is marked with the page number "65." This would indicate that pages 1-64, containing paragraphs 1-57, and which are now lost, originally formed an integral part of the manuscript. But in the left hand upper corner of the first page of the manuscript, p. 65, we find the number "2," which would seem to indicate that the preceding pages, 1-64, had never formed a part of the present manuscript, but constituted separate sheets, or were a part of a separate volume marked "1." In any case the contents of these missing pages is indicated with some exactness in the text of the work itself; and it is on this basis that we have endeavored to restore them. But this matter will be more fully explained in the Introductory Note to paragraphs 1-57.

As we have already stated, the manuscript lacks not only the beginning but also the end. Whether it was ever finished is, indeed, a matter of very reasonable doubt. For the last page of the manuscript (p. 433) ends with a chapter-heading; but the following seven pages are blank! This would indicate that here the author paused from the work,—a work which he never subsequently resumed.

The evidence which we have advanced makes it indubitable that this work on the fibre is the Transaction III. on the Fibre so often referred to in the ECONOMY, and that it is also the work on "The Medullary Fibre of the Brain and the Nerve Fibre of the Body" advertised in 1742 as soon to be published. We have therefore felt justified in publishing it under the latter title and as Transaction III. of the ECONOMY OF THE ANIMAL KINGDOM. The manuscript itself contains only the titles, "The Fibre," "The Arachnoid Tunic," and "Diseases of the Fibre,"—titles which are entered only at the head of the several parts of the work where these subjects are taken up.

The general plan of the published transactions of the ECONOMY was, First, the presentation of "Anatomical Experience," and, second, an "Induction," first presented as a whole, and then taken up, part by part, and commented on at length in separate paragraphs. That this was the plan also of the present work,—or, at any rate, that the author commenced the work on this plan, is clear; for many of the paragraphs are comments on parts of the induction, which, by themselves, do not form a complete sentence; see, for example, nos. 19, 82, 135, 176. But in this manuscript the author has not gathered up the separate parts of his induction into a single and introductory presentation, as in the case of the published transactions, though it is not improbable that he intended to do this when seeing the work through the press. So far as the first nine chapters are concerned this intention seems clearly indicated; and therefore in our translation we have introduced each of these chapters by an added paragraph wherein we present, as a whole, the various parts of the induction treated of in the chapter. After chapter IX, however, this became impracticable. The style of the work there begins to change; the underscored or italic portions indicating the inductions become longer and the comment shorter, until finally the paragraphs consist almost entirely of underscored lines. There is no change in the style of diction, which is maintained at a high standard throughout the work. The change is solely in the plan of treatment. In the beginning this is the same as in the ECONOMY, but later the work becomes a simple treatise with little or no distinction between induction and comment,—a mark perhaps of an intermediate stage between the plan of the ECONOMY and that of the ANIMAL KINGDOM, where the induction, or Analysis, as it is there called, forms the text and the comment is put in the shape of footnotes.

The author has included as a part of his work on THE FIBRE a treatise on the ARACHNOID TUNIC,—and this because the arachnoid is the administrator of the juices around fibres and fascicles whereby these are preserved in their distinctions and uses. He has also included a treatise on DISEASES OF THE FIBRE, as showing the effects in brain and body of disorders in the fibres; for thus their functions are seen the more clearly.

The subject of diseases of the fibre is also the subject of another work by SWEDENBORG, but which is entitled by him, "DISEASES OF THE BRAIN." This work is contained in codex 55 (reproduced in Photolithographed MSS., volume VI.), where it constitutes the appendix to what is called by the author "Transaction III., On the Cerebrum." This work on the Cerebrum is a redraft of Transaction III. of that "first projection" of which we spoke above as constituting the contents of codex 65. The work, DISEASES OF THE BRAIN, is added at the end of the Transaction, but there is no interruption in the paragraph numbers. At the end of no. 639 come the words "End of Transaction III.;" then follows the heading, "Diseases of the Brain," after which comes the paragraph marked no. 640. The numbering continues from 640 to 684, which is a part of chapter VI.; the work itself, however, continues without a break from chapter VI. to chapter XXXVI. The page which contains the commencement of no. 684, like all the preceding pages, is neatly written, but all the following pages, containing the unnumbered paragraphs, are apparently in the style of a first draft. The appearance of a first draft is specially evident in the page containing the continuation of no. 684; for at the top of this page we find a few lines which are the same as the concluding lines of the preceding page; but these are crossed off to the point where the uncrossed portion constitutes a continuation of what has been copied on the preceding page. After Chapter XXXVI. come twelve pages of a first draft on the Skin and Tongue, prepared apparently as a part of the ANIMAL KINGDOM; and these are followed by the last page of the manuscript being a chapter on the Tarantula, and forming evidently a part of the work on the DISEASES OF THE BRAIN. It would appear as if, originally, there had been two manuscripts,—one containing the first draft of the work on DISEASES OF THE BRAIN, and the other containing the neat copy of Transaction III. on the Brain, as rewritten from the "first projection;" that, in this second manuscript, when the author had concluded the rewriting of Transaction III., he had commenced a redrafting of his work on DISEASES OF THE BRAIN; that, in the middle of no. 684 of this redraft he had abandoned the work of rewriting, and, tearing out from the first manuscript the pages already copied, had put the two manuscripts together as one,—crossing off, on the first manuscript or first draft, the few lines that had been copied to fill the last page of the redraft; and finally that, at the end of chapter XXXVI. of the first manuscript there were originally several blank pages, which the author subsequently used for a first draft of a chapter on the Skin and Tongue in preparation of the Part of the ANIMAL KINGDOM on the Senses. Whether or not this supposition is correct may perhaps be determined by an examination of the original manuscript itself.

The work, DISEASES OF THE BRAIN, treats of all the diseases treated of in DISEASES OF THE FIBRE, and of none other; but the fifteenth and last chapter of the latter work, of which we have only the title, is fully written out in the former work where it constitutes chapter VII. The order of the subjects is entirely different in the two works, and, in general, the treatment in DISEASES OF THE BRAIN is somewhat fuller though quite different in nature, and arrangement. DISEASES OF THE BRAIN commences *in medias res* with a chapter on Apoplexy; but DISEASES OF THE FIBRE has four introductory chapters on the general subject of diseases. The former work is, for the most part, clearly a first draft; while the latter is equally clearly a work written out for the press.

These and some other considerations on which we need not dwell, seem to indicate that DISEASES OF THE BRAIN was written prior to DISEASES OF THE FIBRE, and that the latter work is based in some measure on the former,—sentences frequently occurring which are identical in both works. On the other hand, at the head of DISEASES OF THE BRAIN there is a marginal note reading: "In place of a preface consult what I have written in 4to on Diseases of Fibres in general." If this "4to" refers to our present work then the latter would seem to have been written prior to DISEASES OF THE BRAIN,—unless, indeed, which seems highly improbable, the author contemplated writing two works in which the same subject would be treated in two different ways. But the question is as yet obscure and judgment must await further investigation.

* * * *

It is needless to dwell upon the merits of the work here presented. The work itself is now before the reader. *Ipse judicet.* But we may be allowed to here place before a wider audience the brief but eloquent testimony penned by the editor of the Latin edition more than seventy years ago.

"The literary style of this work (says Dr. Wilkinson) is concise and polished. Its order is everywhere vigorous,—after the image of the order of Nature herself whose servant and interpreter, nay, whose high priest, SWEDENBORG must in all justice be called. For his keen sighted induction penetrates into the hidden recesses of the animal body and of the entire world; to each part does he attribute its proper provinces and functions; he illumines them all with analytical and rational light; he fosters them with truly human heat, which is love; and, to an awakened thought and a new-born reverence, he presents the entire organism as a work worthy of the Supreme Deity. He again joins soul to body. He grants and restores the empire of the superior over things inferior, of the spiritual over things natural. And so, our organic body, long the subject of bare anatomy, is presented to us men, and, above all, to our mind, as animated anew. Thus haply we rise from the tomb and corpses of dead sciences to the living and gladsome lights of divine philosophy; and, with sure faith firmly established, we wait with joy for more enlightened times. To God be the glory."

ALFRED ACTON.

Bryn Athyn,
January, 1918.

THE FIBRE

FROM EXPERIENCE.

NOTE. The original manuscript of the Author's work On the Fibre, commences with n. 58. No trace of the preceding 57 paragraphs has thus far been discovered. It is evident, however, from references to them in the body of the work itself, that they consisted of excerpts from the anatomists. The order in which these anatomists are cited is established by references in the text, as follows: nos. 5-8 WILLIS (since, in his works on the Brain the author nearly always begins his citations with Willis, it is probable that nos. 2-4 are also from this anatomist); 12-15, BARTHOLIN; 16-18 LANCISI, VIEUSSENS and RIDLEY; 19-21 MALPIGHI; 22-43, LEEUWENHOEK; 45-51 BOERHAAVE. Of the references given in the author's text, some are quite explicit, and plainly indicate the paragraph number referred to; others give merely the name of the anatomist with a more or less explicit mention of the subject on which he is quoted, but without reference to a paragraph number; in the latter cases we have bracketed the paragraph number to which the reference is now assigned. At the end of each paragraph of the reconstruction we have appended the reference to the text of the present work on which the reconstruction is based.

[1.] This paragraph probably contained a general statement by the author himself introductory to the citations that followed. Confer the similar plan followed in n. 328.]

[2.] WILLIS (*Cerebri Anatome,* Lond., 1664). Within the cavities of the sinuses and within the interstice between the cerebrum and cerebellum are found many fibres, or, as it were, somewhat large and nervous cords, such as we observe, variously stretched out, in the ventricles of the heart. Within the sinuses, and constituted of the various processes of the dura mater, is a winding cavity manifoldly divided into many little cells, as it were. . . . In addition, moreover, to these intricacies and little cells of the membrane, one may observe in the heads of quadrupeds, that in the whole cavity of the sinuses, many cords, or, as it were, ligaments, are everywhere produced from one side to the other. The office of these cords is, in part, that they may hold the sides of the cavity within their appointed limits of opening and dilation; lest they be unduly distended by the vehemently onrushing blood, so as to compress the cerebral way. . . . That these interior processes, and, as it were, transverse cords of the sinuses are conducive to the more convenient return of the blood, we gather the fact that in beasts of burden in whose brain (because they feed and walk with their heads downwards and forwards) there is greater danger of an inundation of blood, these processes are notably large. (Ch. vi. pp. 85-6, 87-8.) [*Fib.* 129, 178.]

[3.] The pia mater lines the openings of all the tortuous windings of the cerebrum; it girds the interstices of both hemispheres; it holds in connection the posterior part of the cerebrum which otherwise would hang loose and lax; and, surrounding its border as with a fringe, connects it with the medulla oblongata. In sum, the entire cortical substance of the cerebrum is covered over by this membrane which is beset with a great number of vascular plexuses. It does not, however, invest the interior surface of the expanse of the cerebrum,—which is called the corpus callosum, and is entirely medullary and white. . . . But within all other recesses of the cerebrum, and also within the folds or layers of the cerebellum, and the interstices both of these two bodies and of the medulla oblongata, this membrane insinuates itself and is entwined between the distributions of the vessels. (i, pp. 16-7.) The pia mater is much finer than the dura mater and consists of a most subtle fibrous texture. . . . Although this membrane is so delicate, yet it is everywhere overlaid with arterial and venous plexuses, and, to some extent, is interwoven of them; so that it irrigates all the spaces of the cerebrum and cerebellum with innumerable rivulets. For, since the region of both brains, and especially of the cerebrum, is extremely tortuous, this membrane is attached to the deepest furrows and the highest ridges of these tortuous windings and gyres, and this in such way that the larger foldings of the vessels are laid down in the valleys, as though hidden for safety. . . , That the wonderful diffusion of the membrane into all the tortuous windings of the cerebrum, and the distribution of the vessels through their inmost recesses, may be the better observed, let the head of a man, or even of an animal, who has died of cerebral dropsy, be opened; for in such subjects the brain abounds with great humidity, and the little bonds whereby this meninx is fastened to the substance of the brain are loosened, so that the membrane with its plexuses of vessels can easily be drawn away and pulled off almost entire. With this pulled off, the folds of the cerebrum will then be bared, and the insertions of the vessels into the deeper cerebral substance will also be perceived. But in a healthy or dry cerebrum the pia mater clings so closely that it can hardly be drawn off anywhere, or separated with a scalpel. (iii pp. 89-90.) [*Fib.* 172, 82.]

[4.] As regards the blood vessels which cover the pia mater, we observe that the arteries and veins, running to each other from opposite sources, not only immediately deliver themselves of their burden by means of individual inosculating shoots, as in other parts of the body, but that, being everywhere twisted together and interwoven, they constitute remarkable plexuses in which, for the most part, are inserted an immense number of minute glands. Such plexuses may be seen . . . scattered everywhere throughout the whole circuit and the interior recesses of the cerebrum and cerebellum, and especially between the openings of the tortuous windings and interstices. This is seen more clearly in the humid or dropsical brain, where the glands, ordinarily so minute as to flee the sight, being swelled by moisture, are easily perceived. (vi, pp. 96-7.) The cortical substance secerns and takes up liquor immediately from the blood, and, imbueing it with a volatile salt, exalts it into pure spirits. It is obvious to everyone that the arteries enter the cortex of the brain by the insertion of an abundance of offshoots, and instill into it a spirituous liquor; whereof the superfluous part is absorbed and carried off by venous ducts, while the more subtle portion thus bestowed, goes into spirits. Indeed the blood irrigates the medullary substance only in very small quantity. . . . The volatile salt which, like a ferment, subtilizes the subtle liquor distilled from the blood, is copiously contained in the cortex of the cerebrum rather than in its center. For the cortex, endowed with a cineritious color, shows by its aspect the spermatic parts with their contained humor, wherein is a great abundance of spirit and volatile salt; nay, by its ammoniacal odor it imitates such parts. (x, p. 126.) [*Fib.* 128, 197.]

[5.] Under the term Nerves we comprehend all those parts, furnished with animal spirit, on which motions and sensations necessarily and directly depend. . . . In respect to the encephalon and the medullary appendix, these parts are like a branching shoot growing about the trunk of a tree; that is, if we take the cortical substance of the cerebrum and cerebellum as the roots, and the whole medullary substance as the stem and bark, then the nervous germination into divarications of nerves and fibres will appear like expansions into branches, twigs and foliage; or, if the encephalon, containing the principal part and potency of the sensitive soul, be taken as the body of some luminary and sun or star as it were, the nervous system will be like a radiant concretion surrounding it. (xix, p. 236.) [*Fib.* 127.]

[6.] Whenever I have opened the bodies of certain persons who had died of long standing paralysis and a most grievous dissolution of the nerves, I have always found that the corpora striata were less firm than any other parts of the cerebrum, being discolored like dregs and with many of the striæ obliterated. Furthermore, in new-born pups who were without sight and could hardly carry on the other faculties of motion or sensation, these striæ, being scarcely fully formed, are seen to be merely crude. (xiii, p. 159.) [*Fib.* 167.]

[7.] In certain animals the structure of the cerebrum is divided into two parts or hemispheres distinct from each other throughout almost its whole thickness. . . . Furthermore, in man, whose cerebrum is more capacious and ample than that of the other animals, each hemisphere is again divided into two lobes, an anterior and a posterior, between which runs a branch of the carotid artery, like a brook between two boundaries, distinguishing them into two provinces, as it were. . . . The cerebrum is thus like a citadel divided into many bastions or forts that it may be the better guarded, and more difficult of attack. Nay, within the several above mentioned partitions, the whole structure of the cerebrum is seen to be still more divided and variegated. For its whole exterior surface is everywhere rendered uneven and tortuous by gyres and convolutions almost like those of the intestines. These gyres, proceeding by a sinuous winding, and, as it were, a spiral circuit, from the anterior part of the cerebrum to its posterior, surround both its hemispheres, one circumvolution succeeding another in a continued duct. In the moist cerebrum, or one that has been kept for some time, the delicate meninx that invests the several parts and binds them together is easily pulled away; and the gyres and folds being then opened and drawn apart, the substance of the cerebrum is seen to be as it were ploughed into furrows; from which furrows arise the summits or ridges of the tortuous windings, not in a straight series but crosswise; in such way, namely, that at the bottom of any given furrow a convolution rising on the right side is carried to the left; then, immediately following it, another convolution is set up, emitted from the left side to the right; and in this order the inequalities of the whole cerebrum are alternately variegated. (x, p. 122-3.) The cerebellum with its gyres and convolutions, is not variegated in an uncertain way like the cerebrum; on the other hand, its folds are disposed in a certain ordered series; for its exterior structure is seen to consist of lamellæ or rings, mutually contiguous and folded together, and girding the whole circuit in a parallel situation. Both regions of the cerebellum, the anterior and posterior, are terminated in the vermiform process. Near these termini, as in twin-poles, these circles become very short; ascending thence towards the summit, as to an equator, they gradually enlarge like the parallel lines in the sphere. These circles are cortical without and medullary within, and the medullary substances of all of them pass over into two large central cores which, indeed, seem to be the same in the cerebellum as the corpus callosum in the cerebrum. (iii. pp. 41-2.) [*Fib.* 69, 89.]

[8.] The nerves are white, smooth, and round. Within the cranium and near their origin where they are covered only by the pia mater, they are softer and more easily disrupted; outside the cranium, where a number of them are almost always colligated together and are also invested by the dura mater, they are somewhat harder and firmer. The nerves themselves, as may be detected by means of the microscope, are furnished throughout their whole extent with pores and passages as with so many cavities thickly set in and mutually contiguous. Thus their syringe-like substance, like Indian cane, is everywhere porous and pervious. Within these little spaces, blandly spring forth animal spirits or corpuscles extremely subtle and of their own nature ever prone to motion; to which is adjoined an aqueous humor, itself consisting of extremely subtle parts, which serves both as a vehicle and also as a retainer. . . . This nervous juice derived from the cerebrum and cerebellum into the medullary appendix, is carried thence, by an ever bland flow, through the nerves into the whole nerve family, and irrigates its entire system. On the equable emanation of this fluid depends the expansion of the animal spirits throughout the whole system. And the substance of these spirits, yea, the hypostatic substance of the sensitive soul itself, is founded on the diffusion of this same humor. (xix, pp. 242-3.) [*Fib.* 297, 142, 188.]

The reader should consult plates V, VI, VII and VIII in the author's *De Anima Brutorum,* and plates I, VII and VIII in his *Cerebri Anatome,* exhibiting the connections between the fibres of the cerebrum and those of the cerebellum. [*Fib.* 91, 147.]

[9.] PACCHIONI. After you have carefully cut away the cranium and turned over, from the forehead to the occiput or to either side, a not inconsiderable portion of the dura mater in such way that the stronger cohesions of the two meninges still remain; and then shortly afterwards have wiped off the dew of the meningeal substance, you will see new drops coming from the substance, and the same kind of moisture, and this even without any pressure of the finger,—a most sure proof, not only that the pia meninx is for some reason externally pervious and perforated, but also that in its foramina or punctures trickles something of the nature of lymph. Moreover, what shall I say respecting that oleaginous lymph which is found between the pia meninx and the tortuous and deep anfractuosities of the cerebrum! This is by no means supplied by the cortical glands of the cerebrum and cerebellum, for after you have wiped off the latter you will certainly not observe anything of the nature of humor flowing out therefrom. Nay, the reverse, since the entire inner surface of the pia meninx, after being further wiped, always moistens, and abounds with a whitish mucus springing from every direction, and this even though it be torn away from the dura mater; wherefore it seems impossible not to acknowledge the true sources of this abundant humor as being in the porosities and lymphatics of the pia mater. . . . That this same lymph abounds in oily particles needs no better proof than sight and touch. If you use your eyes, the pia mater will be discerned, in some cadavers, to be sprinkled over with innumerable round and whitish particles,—a fact to which my attention was called by an observation of that most diligent anatomist Ruysch to the effect that in various places the pia meninx is rich with fat. Moreover, if you touch the cortex of the brain with your fingers, you will not fail to notice that it is extremely smooth as though suffused with a most subtle oil, a fact which I have learned, not without admiration, from a vast number of dissections of cadavers. The truth is also placed before our eyes by the concretions and hydatids of the lymphatics of the pia meninx, wherein we have sometimes seen oil floating at the surface; that is, have seen that the lymph is filled with oily particles of this kind. (*Opera*, Romæ, 1741, pp. 118-9.) [*Fib.* 343, 197, 355.]

[10.] From these glands* emerge innumerable threads which are so many excretory vessels. These lymphatic vessels (so he calls them), intimately associated and entwined with blood vessels from the dura meninx, are implanted in the pia meninx and adhere thereto with the utmost firmness, by the aid not only of blood vessels, but also of many fibres which come from the dura meninx. . . . A great many of these glands seem also fastened upon, and, as it were, engrained in the pia meninx. When these vessels are broken they pour out a liquid. . . . Whether all the lymphatic vessels are contained under the plexuses of blood vessels, is a matter of not unreasonable doubt; for very often, on breaking the connection between the dura meninx and the pia, there come to sight a great number of glands fastened, and, as it were, engrained upon the latter; wherefore, and also by reason of a certain dew, like a very white mist as it were, which remains spread over the pia meninx, I inferred by a bold conjecture that, in addition to the above mentioned insertions and ligatures, there are also implanted in it very small lymphatics. Therefore, by investigating more attentively beyond the exposed complication of vessels, and by slowly pulling the one membrane from off the other, I noticed that both were, in addition, connected by thin threads as it were, which emerge from the glands of the dura meninx. These must be stretched out to a certain length, when, being broken, they will wet the finger, if applied thereto, with a clear humor. The progression of these lymphatics, at least within the pia meninx, is not very difficult to follow, since by adhering to the sides of the blood vessels, they accompany the latter and follow their every least ramification; for they are seen both on the surface of the pia meninx, and in the separate portions thereof which clothe the windings of the cerebrum,—upon which latter they bestow a not inconsiderable moisture. When these portions are exposed to the light they exhibit most slender white vessels not unlike the substance of the pia meninx, and for the most part interlaced with blood vessels. . . . Although the pia meninx invests the cerebrum everywhere and pervades its cortical gyres and interstices and the walls contiguous to the falx down to the corpus callosum, nevertheless it is always associated with lymphatic vessels; but I am not yet able to say whether these penetrate the medullary substance, although I applied all intelligence to the enquiry. (*Ib.* pp. 128, 130.) [*Fib.* 355, 197, 172.]

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*The glands of the longitudinal sinus now called the Paccionian glands.

[11.] Bartholin (*Anatome*, Ludg. Batav., 1686). The external part of the cerebrum is properly and strictly called the Cerebrum, and is that whole soft portion, forming the external circumference, which appears of a cineritious or yellowish white color. . . . This external substance is as a cortex or bark; particles whereof, according to Malpighi, are also found in the ventricles, at the beginning of the spinal medulla,* and in the long spinal tract outside the brain. The internal part is the rest of the cerebrum, hidden from sight, somewhat harder and more compact, and of a whiter color, which may be called the medulla or marrow; wherein, and not in the cerebrum itself, are situated the ventricles, commonly so called. . . . The external surface of the cerebrum is anfractuous, having various convolutions and gyres like those of the intestines; of which gyres it must not be said with Erasistratus, that they are made for the sake of the intellect, since asses also have them; nor as declared by Aristotle, for the sake of lightness, since they are wanting in such fleet animals as mice, hares, rabbits; nor, as others think, as being without an end or use; but as existing in order that the vessels of the cerebrum may be the more safely conducted through these windings without danger of rupture from the continual motion. . . . The substance of the cerebrum is peculiar, such as is no other in the whole body. Hippocrates likened it to a gland, by reason of its color and abundant humor. It is soft and moist in order to the more easy impression of images and concepts, for it is the seat of imagination. It is not so soft, however, as to flow apart, but it has a consistent softness, so that what is impressed may remain for some time; for the cerebrum is also the seat of memory. . . . The Cartesians make the cerebrum to be woven of soft and pliable fibrils, mutually contiguous, and with porous interstices; by which fibrils the images of objects are impressed on the cerebrum. (Lib. iii, Ch. iii, pp. 468-472.) [*Fib.* 58, 80.]

12. The nerve is the common organ, long and smooth, for the animal faculty and for the conveyance of the animal spirit which is to be carried off to the parts of the body. . . . Aristotle held that they arose from the heart, and he is followed by Alexander, Averroes and Apono; they say, however, that this origin is by means of the brain. Others, such as, of old, Pythagoras, and, in our own time, Cesalpin, Reusner, Hofman and Martian, hold that the nerves are nothing but veins and arteries continued, and finally become nerves; not correctly, however, for we see in the brain no conjunction of nerves and arteries by anastomoses; moreover, when one of the arteries of the head is injured or cut, no convulsion follows; and lastly, the distinct origin of the nerves can be seen in the brain, just as that of the arteries in the heart. . . . A matter or blood is supplied by the arteries to the

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*What is meant is the medulla oblongata.

brain and its membranous parts whereby the animal spirit is renewed; for this purpose also arteries are inserted in the nerves, as is the case in the brain, and especially in their tunics. Willis has well said that "as flesh, membranes and bones are all irrigated with blood, so, by aid of the microscope, we are able to detect that the least bodies of certain nerves, together with their fibrils, are girt about with arterial and venous capillaries." . . . The end and use of the nerves, is, that, like canals, they shall convey the animal faculty received with the animal spirit from the brain, to the sensory parts, as to the eyes, ears, etc.; to the motory parts, as to the muscles; and to almost all parts, that, in general, they may sensate and may recognize the things that bring them discomfort. Therefore, the nerves inserted in the parts bring to those parts either sensation or motion, or both. Nor can there be any voluntary action, nor any sensation, without a nerve; and, therefore, when the nerve is cut the part is at once deprived of sensation and motion. (*Libell.* iii, *cap.* i, pp. 659-660.) [*Fib.* 128, 142.]

13. In shape, the nerves are long, round, and smooth, like channels; but without a cavity, which could be found neither by myself by inflation or the stylus, nor by others by the microscope; thus unlike veins and arteries; for these, together with spirit, carry also blood, while nerves carry spirit alone without blood. . . . All nerves, like Indian cane, are without any manifest cavity. But, lest the penetration of their bodies be impossible, they have pores through which the subtle spirits flow. . . . The nerves, moreover, without exception, consist of many nervous fibres or filaments mutually held together by little membranes. . . . Descartes supposes that the nerves have valves which, when open, admit the animal spirit, and when closed, prevent its return. . . . But it would seem possible for the spirits to be retained in the parts, since the soul which has directed them to the valve directs them further to the parts themselves; for up to the present, no anatomist has ever observed valves. Nor are subtle spirits impeded by valves. Nor, finally, could apoplexy or paralysis easily occur if the spirits could be held in the parts by valves. Descartes rejoins that, by a general law, Nature has set them in all parts of our body, whereby all matter should be led in its accustomed path and be prevented from returning. But Nature has made this provision for material things not for things subtle and spiritual. (*Ib.* pp. 662-5.) [*Fib.* 209, 188.]

14. The nerves are not all equally hard or soft; hence, with Galen, some are soft and others hard. The former he calls sensory nerves, and the latter motory. The hard nerves are more suited for motion, and the soft for sensation; therefore the organs of sensation receive the soft nerves, in order that these may be affected and may be passive to external sensations. But all parts that have voluntary motion receive the hard nerves, because what is hard is more suitable to action, and what is soft to passion. (*Ib.* p. 666.) [*Fib.* 297.]

15. The use of all the nerves is to carry animal spirit to all the parts, for the sake of sensation and motion, as is evident from their injury. For when obstructed in their beginning—if the obstruction be total, both sensation and motion perish and apoplexy results, or if it be on one side there is privation of sensation and motion on the other side; if they be cut, the motion of the side into which they were inserted is destroyed. (*Ib.* p. 666.) [*Fib.* 142.]

16. LANCISI (*De Motu Cordis,* Romæ, 1743.) Fallopius was the first to detect the natural ganglia of nerves, that is, those which exist in a state of health; and by reason of their figure he called them Olivary Bodies. (*De Gangliis Nervorum,** p. 397.) There is no one skilled in the dissection of animals or men, who does not know that from the cervix throughout the abdominal region there are found in the trunks of the nerves little ganglia or rudiments of ganglia, in which nerves of different orders come together and form a larger and somewhat harder stem out of which, as from a trunk, little branches afterwards go forth and are distributed. No definite number can be assigned to them, for, in their construction, as observed by their discoverer Fallopius, nature has used great variety. . . . The nerve branches which go forth directly from true ganglia are fleshy and muscular and go off into various kinds of nervous tendons as it were; when, afterwards, they are distributed to one or other of these, they are in like manner invested with a tendinous tunic, and frequently form a plexus,—which is not to be considered as a new ganglion, but, for the most part, as a portion or member produced and prolonged from the upper ganglion. (*Ib.* p. 398.) Some nerves, enclosed only in a loose membrane as in a sheath, are seen to turn off into various branches by simple departure and disjunction from their associate nerves. Of a truth, however, such nerves had already been profoundly distinct from each other even in the medulla spinalis and in the brain itself, although they took their course side by side. Other nerves, again, strongly protected by a more robust tunic and interwoven with fibres not only externally but also internally, depend on some superior ganglion. Nerve complications of this kind (often called nerve plexuses) are not to be considered as absolute and perfect ganglia as soon as they swell into a slightly oval or barley-shaped figure; but they are to be taken either as offshoots of superior ganglia, or as colligations of a number of nerves such as nature herself sometimes weaves by a certain arrangement between the perfct ganglion and the simple tunic. (p. 399.)

The true ganglion is seen to consist of two cones commingled in their bases and joined together in the their middle portion, the upper apex of these cones constituting the beginning, and the lower the end or tail. . . . It is described by Fallopius as "a longish body of the shape of an olive, flesh-colored in appearance and nervous in substance, and somewhat hard." Willis adds that "the plexuses are like knots in the stem or trunk of a tree." Vieussens gives a more accurate description of the texture of the ganglia, as he calls them, when he affirms that "they are woven of nervous fibres, arterioles and little veins covered over with pia and dura mater;" he adds that "their larger fibres emulate fleshy fibres both in color and in substance." . . . But so far as I know, no one has followed up the internal substance of the ganglia, or rightly searched into the order of their fibres, the beginning of these fibres, their situation, and the manner in which they go off. (p. 400-1.)

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*This little treatise is printed as an appendix to the edition of *De Motu Cordis* noted above.

In order that the muscular complexion of fibres in the ganglion might be made more plainly apparent, we selected the largest ganglion (the superior cervical) in our body. . . . After the intercostal nerve* has passed through the foramen of the cranium it receives several branches from other nerves, namely, the optic, the ocular-motory, and also the gustatory and auditory nerves. Therefore, the nerve of the ganglion is made up of a number of nerves, which, gathered together into a fascicle, seem gradually to embrace the internal carotid until it gets new supplies of fibres both from the posterior nerve of the par vagum, and from the motor nerves of the tongue. Near the second cervical vertebra, the nerve, thus enriched with fibrous shoots, then enlarges to a ganglion. (p. 402.)

The ganglia are never appended or attached to a single nerve only, but they admit, collect, commingle and colligate many nerves. Of these, some penetrate the ganglia from above and almost perpendicularly; some transversely or obliquely. Most of them go to the internal substance of the ganglia, but some are distributed only to the membranes or outer covering. Wherever a true ganglion is found, the more conspicuous nerves which penetrate to its internal and almost medullary substance, both from above and from below, appear reddish, or slightly tinged with a sanguineous purple; while the other nerves which proceed, either from the brain or from the medulla spinalis, without ganglia, and especially the par vagum and its branches before they commingle with the ganglion, are entirely white. Everywhere within the ganglia are observed blood vessels flowing in and out, and visibly derived from the neighboring trunks. The mass of a ganglion is larger than the aggregate of all its ingredient and egredient vessels; from which circumstance, we must conceive for their production the necessity of the concurrence not only of the ordinary vessels, but of some peculiar body, raised up not so much by the coherence and complication of the above mentioned nerves and blood vessels, but by new organic parts.

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*Now called the trigeminal.

It is now time to spread before the reader our observations respecting the internal substance of the ganglia. We took the upper ganglion in the neck, which is the largest of the ganglia; and generally the left ganglion, both in man, and, for the more easy discerning of its small parts, also in the horse. In both cases we noted that this ganglion is located between the first and second cervical vertebra near the internal carotid and under the jugular vein and the vagus nerve. It receives its arterioles from the internal carotid and sends its veins into the jugulars; it takes many nerves from the par vagum. With respect to lymphatics we dare make no affirmation since none came under our eyes, but we deem it probable that some will be found there; for where there is a sheathing tunic there lymph ducts are usually present.

The ganglion is involved in three membranes,—which tunics, we doubt not, take their origin from the membranes of the brain, though around the ganglion they slightly increase and thicken by the accession of new fibres. The outer of these membranes invests the ganglion loosely like the tunica vaginalis invests the testes; so that if compressed with the fingers, the entire body of this ganglion is seen to slip out hither and thither like an inner kernel and to slide off in any direction whatever. This membrane is contextured of somewhat gross fibres approaching the nature of muscular fibres, and which, by reason of being mingled with blood vessels, are of a reddish hue. On its internal surface it is lubricous, being softened, like the pericardium, by a mild fluid. . . . The second membrane invests the ganglion somewhat closely, and is distinguished by finer fibres, but more complicated and coherent with each other. The third membrane is wholly tendinous, and is so closely conjoined and interwoven with the body of the ganglion that it can in no way be separated from its surface without being torn and lacerated; it deserves therefore to be called a circular tendon whose fibres are wholly continuous with the fleshy fibres of the ganglion itself. The small and smooth nerves, or rather nerve tendons, not yet deprived of their membranes, that go from the ganglion to the neighboring parts, especially the muscular parts, and the blood vessels,—more particularly the arteries,—of the præcordia, are taken not from the external membrane of the ganglion but from its interior substance. (pp. 403-5.)

Its reddish nervous branches are carried to the muscles of the neck, pharynx, larynx, and tongue, and to the membranes of the neighboring parts. . . . Fibres of this nerve descend by the œsophagus and are scattered and disseminated through the orifice of the stomach, the intercartilaginous membranes, the muscles of the trachea, and everywhere in the bronchia. Other nerves are carried to the neighboring arteries, especially the carotid. . . . Some go straight down as far as the trunk of the aorta and with the latter go to the substance of the heart; muscles go all the way to the extremities of the arteries and their insertions into the muscles and the beginning of the veins. . . . A not inconsiderable nerve after penetrating the thorax between the mediastinum and the pericardium proceeds to the heart. Moreover the nerve from the cervical and second ganglion wonderfully intermesh with the cervical nerves and the branches of the par vagum, with the intercostal nerves which go out from the dorsal vertebræ and with the fibres of the phrenic nerve. (pp. 406-7.)

When the ganglion has been boiled and completely divested of its covering of tunics and laid bare, it exhibited to our sight on its outer surface a kind of nervous network tenaciously entwined in its membranes. Under this network and arranged in elegant order are seen fleshy fibres extending from the vertex of the ganglion to its lowest point; and which were so arranged that they seemed to resemble the beautiful rind of a melon divided by furrows into equal segments. Moreover, emerging from the intermediate commissures of the fibres are found innumerable fibrils which are joined to the inner tunic and entwined therewith. Whenever the ganglion is forcibly freed from its membranes and uncovered, these fibrils are necessarily rent and torn. After the ganglion had been long boiled we commenced to gently open and loosen it with our nails on both sides, until gradually we came to the centre. The internal substance of the ganglion was then seen to be compacted of the most delicate fibres which almost escaped the naked sight; but when examined by the microscope, it became plainly apparent that they were fleshy fibres, and that they proceeded from a white tendon which, like an axis, was stretched in a straight line from the upper to the lower point of the ganglion. These fibres are carried from the above mentioned fibres, as from the stem of a feather, not only from both sides but also in every direction, or like rays directed to the entire surface. The entire body of the ganglion may therefore be said to be framed of two kinds of tendons, and of a double series and direction of fleshy fibres; for the first tendon is external and is made up of the two outmost membranes and of the scattered little nerves running through them,—by which tendon the whole mass of the ganglion is not only covered but is also protected and strengthened for the exercising of muscular force. The second tendon, descending through the centre like an axis, is that from which the pinniform fibres are observed to arise, or, at any rate, to which they are bound. (p. 407.) Since the fleshy fibres are of this twofold order, it must of necessity be, that when either order of fibre is stretched by some fresh curling or swelling induced on the individual fibres, it becomes shorter, and by reason of this, the upper and lower points of the ganglion are brought considerably nearer to each other, or, from being of a spheroidal figure the ganglion approaches more to the figure of a sphere. But since in this contracting or decurtating motion it can never happen that the upper vertex will descend much to the lower, since the former is strongly attached to the fulcrums of the bones of the vertebræ and cranium by nerves and membranes, it follows of necessity, that the lower point will ascend the more to the upper and will draw with it its tendons and the parts wherewith these tendons are bound and colligated. (p. 409.) [*Fib.* 237.]

17. VIEUSSENS (*Neurographia Universalis*). The brain consists of two distinct substances, a cineritious and a white. The cineritious substance is much softer than the white. When more closely inspected through the microscope, it is seen to be composed of innumerable globules combined together, and, to a certain extent, emulous of the figure of an oval; so that it closely resembles a body made up of conglobate glands. These glands mutually compress each other. Hence arise obtuse angles, as observed by the learned Malpighi, which are distinguished from each other by little intermediate spaces that are almost equal. This is proved by an experiment in which spirit of wine colored black is poured upon the cortical substance of a brain that has been boiled and then stripped of its pia mater; the spirit of wine so enters into the little spaces between the external glands of the cortical substance, that after it has been gently wiped away with a piece of cotton, innumerable little portions of it will be easily seen, even without the microscope, occupying the said spaces and showing up the glands which they surround. This would not be the case if the cortical substance consisted of particles of a shape other than oval or oblongo-rotund; for, being very soft, they would lie so close to each other that not even the least space would be left between them for the reception of the dark-stained spirits of wine. . . . We, therefore, assert with Hippocrates that the brain, in part at least, is glandular. "The head (says he) also has its glands, namely, the brain which is like to a gland;" and he adds, "For the brain, like a gland, is white and friable." (*De Gland.* VII.) The cineritious substance either occupies the outer circuit of the cerebrum and cerebellum, whose medulla it penetrates to some depth; or it is found in the very centre of the cerebrum, or in the medulla oblongata. When it occupies the outer circuit of the brain it is called cortex, cortical substance, or external cineritious or glandular substance. The white substance of the brain, which we shall call the medullary substance and sometimes the medulla, is made up of innumerable fibrils connected together and distinguished into many fascicles as it were. This is plainly apparent when this substance is boiled in oil, for it may then be easily divided into those innumerable fibrils, of the mutual connections whereof it is made up. In their natural situation these fibrils lie so close together, that is, when there are no glandular particles between them, that no least space can be observed between them, and they constitute one continuous body. . . .

In the cerebrum, cerebellum and medulla oblongata, this white substance is so closely applied to the cineritious substance, that the two coalesce. And yet they are utterly different from each other; for, besides their difference in color, the white is harder than the cineritious, and has narrower pores. . . . Moreover the cineritious substance is seen to be made up of oblongo-rotund particles emulating globules; while the medullary substance consists of somewhat long fibrils, variously inflected, which are so enfolded in each other, and so intercommunicant, that they produce the appearance, as it were, of a spongy body through which runs the animal spirit in many distinct and inexplicable ways, so that it accomplishes within it many distinct and inexplicable motions, for the diverse ratio whereof thoughts are excited in the soul. (*Lib.* I. *De Cerebro,* cap. x.) [Fib. 197, 80, 58, 131, 127, 142.]

When the two hemispheres of the cerebrum are drawn apart the intermediate medullary substance comes to view. Veslingius calls this substance the Corpus Callosum, but in our pages we name it the True Fornix. (cap. xi.) [*Fib.* 82.]

It is extremely probable that the arteries irrigate only the glandular substance of the brain; for in this cortex or outer glandular substance we discern innumerable arteries, but in the neighboring medulla we find none or very few,—which would not be the case if the medulla were the last term of their insertion. Moreover, the arteries of the lower medullary region are greater in number and coarser than those of the upper; they seem merely to pass through the latter in order that they may reach the cineritious substance of the striate bodies, whither we have quite frequently found them tending. Therefore all the vessels that penetrate the medulla of the cerebrum are, in all probability, extended to its cineritious substance where they are terminated. . . . We support this opinion by an experiment in which we tied the carotids near the middle of the neck, and repeatedly injected into one or other of them spirit of wine colored with saffron. When the head was opened, only the cineritious substance of the cerebrum was found imbued with the saffron color; nay, the white and natural color of the medullary substance was unchanged, and many of the vessels running through it were seen to be filled with the saffron injection. This seems to be a sure sign that, in the above mentioned experiment, none of the injected liquor was diffused through the medullary substance. The liquor was injected into the carotid without great force, and in sufficient quantity only; lest by the rupture of its offshoots the liquor which was to be carried to the cineritious substance of the cerebrum be diffused through its medulla. From the above we may infer that all the vessels entering the substance of the cerebrum are terminated in its cortex, and that the arteries do not connect with the veins; for if the liquor flowing from the arteries fell immediately into the veins, then, on the completion of the injection the cineritious substance would not be tinctured. There should therefore be no doubt but that the arterial blood first enters into the substance of the cerebrum* and its membranes before it is taken up by the veins. (*Ib.* cap. vi.) [*Fib.* 137.]

See Vieussens' Figure of the cerebrum cut along the hollow of the lateral ventricles and showing the cineritious substance mingled with the medullary. In the description of this Figure he calls the medullary portion of the cerebellum the Medullary Centre of the Cerebellum. (In Manget's *Bibleotheca Anatomica,* II, Plate lxv.) See also his Plates where he shows the spirals of the cerebellum, and the interweaving of the cerebellar fibres with the cerebral. (*ib.* pl. lx, fig. 2; lxi, fig. 1.) [*Fib.* 60, 94, 91, 147.]

18. RIDLEY. (*Anatomia Cerebri,* Ludg. Batav., 1725.) The brain is that large and almost spherical body which, under the old method of dissection, first meets the sight. It fills the largest part of the space contained in the cranium, and consists of two substances, first observed by Archangelus Piccolomineus, differing from each other in color, consistency, and also in function; the one is compact, white, medullary or fibrous, and the other soft, of a cineritious color, and glandular. . . . The curious Leeuwenhoek made a far deeper scrutiny into these two parts [than Malpighi], being probably aided by better glasses; and from what occurred to his view, he called the cortical part a *pellucid, vitreous, oily substance* (*De Struct. Cer.* p. 37), by reason of the position of the globules swimming therein, which is so close and regular as to allow passage to the rays of light without refraction; contrary to what obtains in the second or medullary part of the brain wherein they are so disposed that the light cannot go through them in straight lines; in consequence, by reason of their slight distortion, they are made to appear white. (cap. XI, pp. 87-90.)

I am induced to believe that the cortical portion is nothing but an aggregation of many vessels containing various kinds of fluids. Some of these vessels contain the much compounded liquor commonly called blood. There is another kind of vessel which receives and contains a more simple fluid, of a thin and transparent nature, and which, when found in certain parts of the body, bestows upon the vessels wherein it flows the name lymph-duct. But in those vessels which we take to constitute the ample substance of the brain, both cortical and medullary, it may be called animal fluid. I regard this latter kind of vessel as being either an extension of some artery which by reason of its minuteness is rendered fit to contain only a liquid such as that of which we have just spoken; or a tubulous production of the same kind of artery corresponding in the proportion of its opening or pore to the figure and size of that fluid which nature intends it to receive. From the same accurate examination carried on by aid of the microscope, it ap-

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*By *cerebrum* Vieussens here means the cortical substance; see n. 11, 21, 58.

pears that the medullary part of the cerebrum has the same constituent parts, but, to a certain extent, arranged in a different way, by reason whereof this part appears whiter than that observed above. I am inclined to the opinion that some, if not the greatest part, of this whiteness may be ascribed partly to the narrowness of the vessels containing the above mentioned pellucid substance, which are found here,—which narrowness is such that it is incapable of taking up any fluid whatsoever, which has not first been reduced into the most minute particles, a process which comes under the name of Leptometry. I should therefore take these ultimate vessels to be nothing else than the numerous still further capillary productions of the cortical vessels; so that the red vessels, or vessels of the blood, cause them to be gifted with a pore of such kind as renders them fit to receive only that most subtle, fine, and mild liquor, which, I take it, is the true medullary and nervous juice, which, when contained in its own proper capsule, and when a number of the latter are gathered together into one fascicle, and, for the purpose of their egress from the brain are involved in denser and stronger coats taken from the two outer membranes of the brain, constitutes that part which we call a nerve. (*ib.* pp. 91-3.) [*Fib.* 58, 142, 127, 137.]

There are nerves which exercise only sensation, such as those which pertain to the various sensories. To these belong the olfactory and ocular nerves [1st and 2d pair], and also the soft processes of the auditory nerve [7th pair], some branches of the fifth pair, and perhaps also of the ninth for the exercise of taste. . . . Other nerves exercise principally the function of motion. Such are the nerves of the entire nervous system with the exceptions mentioned above. In still others both motion and sensation are exercised in a greater or less degree in proportion to the diversity of the fibres of which they consist; such are the nerves of the fifth and ninth pair. (cap. XVII, pp. 154-5.) The seventh pair or auditory nerve . . . consists of two distinct processes, one of which, being destined for motion, is rounder, harder and smaller than the other which is destined for sensation. Although they seem to have the same origin, . . . a deeper examination shows that this is not the case. For the former or hard portion takes its origin from the medullary stem not far from the place where it first comes to sight, while the latter rises far removed from the transverse process or processes, namely, in the passage to the fourth ventricle. (*ib.* p. 148.) [*Fib.* 242.]

19. MALPIGHI (*Opera Omnia*, Ludg. Batav., 1687, vol. ii). In the brain of perfect red-blooded animals I found the overspread cortex to be an assemblage and congeries of minute glands. In the gyres of the cerebrum and in those drawn-out little quasi intestines wherein the white roots of the nerves end, or, if you prefer, whence they arise, these glands are so adapted to each other that their congeries forms the exterior surface of the cerebrum. They are of an oval figure, by

being compressed all around by the adjacent glands; whence arise certain obtuse angles and a great number of intermediate spaces almost equal in size. Their outer portion is covered over by the pia mater and its blood vessels, which penetrate deeply into the substance of the glands; their inner portion puts forth a white nerve fibre like a true vessel, as the lucidity and whiteness of these bodies permit us to observe. Therefore the white medullary substance of the cerebrum results from the connection and confasciculation of a multitude of these fibrils, and if the nature of the cortex may be explained by a familiar example, no better one would occur than the structure of the pomegranate where the symmetrical structure of the granules presents the appearance of that assemblage of cerebral glands of which the cortex is composed; while the fibres issuing from each granule and conveyed through the membrane, exhibit a rude image of the cerebral medulla. I remember also having seen some young dates which, hanging on both sides of the stem, resembled the glands of the brain, while the vessels or fibrous bodies from which the individual dates hung, being gathered into a fascicle, were analogous to the second or hard (*callosum*) or medullary body.

But these cerebral glands are seen with difficulty in the raw brain, even though it be the large brain of perfect animals; and this because by the tearing away of the pia mater they are lacerated, and their coterminous borders are not easily distinguished by reason of their lucidity, nor the spaces between them on account of their softness. They are more easily seen in the boiled brain; for their substance, when thickened by the boiling, shows the intermediate spaces more opened, especially at the sides of the furrows; by peeling off the pia mater they become still more evident, especially if they be examined while still warm. You will see the distinction between these glands after you have poured ink upon them and then softly wiped it off with a piece of cotton; for the intermediate spaces are then blackened so as plainly to exhibit the outlines of the glands. You can readily see the same glands in the boiled brains of birds and fishes; thus the structure is the same in all animals. According to Joan. Kentman, Joan. Pseil seems to have anticipated this discovery in his observation of a stone found in the cerebrum, which, like a mulberry, was a conglobate of minute roundish acini of a cineritious color; it had probably been produced by the petrification of the cortex and had retained the natural figure of the glands. These cortical glands, thus tortuously arranged, compose the outer gyres of the cerebrum and are appended to the medullary fibres or vessels rising therefrom; so that wherever the gyres are cut transversely, a determinate and firm mass of glands is always found overlying the medulla; and the same can be seen even more evidently in the cerebellum. The substance of the cortex observed in the ventricles of the cerebrum, and again at the beginning of the medulla spinalis,* is of the same character; for after boiling, it exhibits the same form and the same characteristic glandular substance as is found in the glands located in the outer region of the cerebrum; with this difference, however, that the former glands are set among the excurrent nervous bodies, so that the protuberances of the ventricles are made up of nervous vessels with interspersed cortical glands. Moreover, in the interior portion of almost the whole of the medulla spinalis, the cortex which I have described, retains the same glandular character and is everywhere irrigated by blood vessels; and in the part of the spine which issues from the cerebellum and cerebrum under the pons Varolii at the supposed ventricle of the cerebellum, cortical glands of this kind are scattered about in different places; for under the outmost surface, which is fibrous and nervous, is spread a large portion of such glands, especially under the pons itself. Little portions of these same glands are also found within, where they are mingled with the medullary substance. (pp. 270-1. *De Cerebri Cortice,* cap. i.) [*Fib.* 80, 127, 58, 60, 61.]

20. The glands in the cerebrum, cerebellum and medulla oblongata have need of blood vessels just as do the other glands of our body, both conglobate and conglomerate. . . . Therefore, in the mass of the cerebrum and cerebellum we found remarkable and numerous ramifications of arteries and veins,—such certainly as are to be met with nowhere else in the body; yet in such a way that the trunks of the arteries were not always accompanied by veins; this we have especially observed in fishes, in the interior surface of whose ventricles there runs only a single blood vessel. This, however, is undoubtedly true, namely, that every single gland of the cortex is bedewed from the extreme ends of both arteries and veins. In the more perfect animals, therefore, it is clear that the blood vessels, by means of the meningeal membranes, irrigate the extreme glands of the cortex, of which the cerebral gyres are composed; so that, in the pia mater, there is visible a network of vessels, the outgoing offshoots of which penetrate to the inmost parts of these cortical glands. Hence, when the pia mater is torn away, the soft structure of the glands is lacerated to no slight degree, and if the glands themselves are cut, there emerge points, still retaining their red color, which have broken forth from the vessels.

That nerve fibres of this kind are to be classed as vessels, seems to be indicated by the well known fact, to wit, that when they are cut, a copious juice flows out, resembling the white of egg and coagulable by fire, as I have observed in a dissected nerve of the arm; nor does the outer shape of these vessels and their propagation afford any objection; for the medulla spinalis exhibits a fascicle of straight tubes; and, although each one of these conspicuous nerves is made up of many little cords as it were, yet we cannot on this, base even the slightest conjecture which would deprive the nerves from being classed as vessels; for in plants, we see with the naked eye that each fibre is plainly composed of many tubes enriched with numerous vessels. The point is further proved by the complication of the fibres, or by the looseness of the nervous vessels representing a sort of rough network. For it is nature's accustomed way, especially at the ends of vessels, to form a network, as we find is the case in the extreme ramifications of arteries and veins; and, if we may add confirmation from an analogous example in plants, there are not wanting exactly similar structures in the fibres that compose the bark of the vine, and of other trees and plants. In bulbous plants also, such as turnips and the like, and likewise, in the stem and leaves of the Indian fig, is observed a netlike propagation of the fibres in every direction, similar to the complications of the nervous fibres in the cerebrum, cerebellum and medulla spinalis. And since it is beyond doubt that the vegetable fibres which form this netlike plexus must be classed as vessels, since they emit jüice and are perforated, therefore we must philosophize in a like manner in respect to our nervous fibrils or vessels the propagation whereof is effected by nature in exactly the same way. . . .

**I. e.*, in the corpora striata and optic thalami.

The implication and combination of nervous fibres in the cerebellum present the appearance of the branching trees described by Cortesius and others, and which, I find, nature endeavors after in exactly the same way in the cerebrum. For if the gyres of the cerebrum with their contained cortex be cut or lacerated transversely we find a like appearance of a tree with its branches and bark. You will see this appearance at once in a transverse section of the whole brain or of any of its parts. . . .

So great is the distinction of the fibres or nervous vessels in the whole tract of the cerebrum and cerebellum, and especially in the ventricles of fishes, birds and also of perfect animals of the earth, that no greater can be conceived of. The visible intermediate spaces, and also the blood vessels with their continous ramification, give plain indication of the interspaces between the fibres. From the above we may conclude as to the error of Velthusius' opinion, who, judging from the works of chemists, likens the brain to a sponge, in order that the defecation of the animal spirits may be accomplished therein. For, although we find in the cerebrum a net-like interweaving of fibres, still the humor of these filaments is not to be carried down by external adhesion, nor is it attenuated and purified from foreign substances, by means of the folds, as is the case in sponges; for the whole work of separating and purifying is perfected in the inmost structure of the cortical glands; and the humor which then issues from the glands, enters into the hollow and tubular fibres, and, by a continuous path, is sent off into the underlying parts for the performance of divers offices;

as is the case in the tubular stems of vegetables, as intimated above. So that this netlike complication of fibres is a necessary property of vessels, in that they carry nourishment or other like principle. (pp. 273-4, cap. iii.) [*Fib.* 128, 127, 142, 131, 61, 166.]

The medulla spinalis is a fascicle of nerves which, when begotten of the cerebrum, is divided into parts,—by whose circumvolution are formed the sides of the ventricles,—and ends in the cortex, wherein, that is, in the smallest clusters of its glands, the extreme roots of the nerves are implanted. The same is also the case in the cerebellum, except that the nerves issuing from the pons Varolii, while they go on to the cerebellum, derive an origin also from the glands of the cortex existing in the pons. And since a large quantity of cortical substance is observed in the ventricles and at the head of the medulla spinalis where are situated the interior prominences; and since, when these prominences are laid open, fibres are observed which are continuations of the nerve, we must perforce conclude that the nerves themselves are produced also from these interior glands. Therefore the fibres of the optic nerve, although they are seen to have a further progress into the cerebrum and cerebellum, yet, since they strongly adhere to the cortical eminences of the ventricles, are most likely equally rooted in these also. (p. 275, cap. iii.) [*Fib.* 127, 61.]

21. Hippocrates in his book concerning Glands classes the brain as a gland, because like glands it is white and friable, receives humidity and passes it off, begets hairs, and is subject to the diseases incident to glands. Piccolomineus, if I mistake not, was the first to observe the difference, and also the division, in the parietes or mass of the brain. For he called the cineritious or livid-white body which first meets the eye, the cerebrum proper, and the enclosed shining and more solid body the medulla; and, in newly killed animals he separated these two substances,—distinguished from each other in color, firmness, and interstices or lines,—with the utmost dexterity. . . . In the more perfect red-blooded animals, and also in the larger fishes, which I have had the opportunity to observe, I have observed this cineritious substance called the cortex. It is not only spread around externally like the bark of a tree, which envelops its centre only on the outside, but in red-blooded animals, a portion of it is placed around the outmost appendages of the corpus callosum, while the remainder is dispersed about in the ventricles, especially at the beginning of the medulla spinalis, where you will find little fringe-like parts of the medullary and white substance scattered about and shut in; the eminences that make the ventricles falcated also consist of cortex. Furthermore, in the long tract of the spinal marrow outside the brain, you will observe this same cineritious substance, placed, not in the circumference, but in the inner part where a sinus has been observed by many anatomists. In fishes also, in the larger ventricles, the inner envelope and covering is com-

posed partly of medullary substance and partly of cineritious substance or cortex; for that part which is connected to the varicose appendages from which the medulla spinalis is commonly supposed to take its beginning and which is prolonged towards the anterior part of the cerebrum, is cineritious; but the white substance which had lain under the corter soon breaks out and occupies almost the whole centre of the ventricle; and this is then again covered over by cortical substance coming up from underneath and in which are remarkable plexuses of blood vessels. In the brain of fishes also, at the beginning of the medulla spinalis where two appendages emulating the form of intestines are placed on either side, the cortex is almost everywhere commingled with the medulla. . . . As to the medulla of the cerebrum, *i. e.*, the corpus callosum, it is said to be more solid than the cortex, and to be surrounded with veins and arteries, namely, for the purpose of filling up the intercepted spaces; but as I could plainly observe, under the microscope, in the brains of fishes, and less plainly, in the brains of other more perfect animals, this is not correct; for it is clearly evident that this whole white portion of the cerebrum is divided into closely rounded fibrils not unlike those white bodies or intestines which compose the mass of the testicles. In the ventricles of the brains of fishes, these fibrils are so plain that when observed against the light they present the appearance of an ivory comb, or of an ordinary church organ with its pipes. I have observed the same fibrous nature in the brains, both boiled and raw, of oxen and similar animals; but it becomes most plainly evident in the posterior region of that portion of the medulla spinalis which lies within the cranium. At the sides of this beginning of the medulla spinalis you will see these white fibres of the cerebrum extended through the middle of an abundance of neighboring cortex, and you will also observe the same structure in the extreme appendages of the corpus callosum; for the fibrous bodies of which the arch of the ventricles is woven, finally end in, as it were, ragged fringes, or in productions after the manner of gyres, and these, not unlike the multitudinous roots of plants, are immersed and implanted in the cortex, which thus serves the turn of soil or earth. What is the progress of these fibrous bodies of which the medullary mass of the cerebrum is composed, is not easy of determination; for, by reason of the tortuous cavities of the ventricles in the more perfect red blooded animals, and the complicated substance of the cortex, to say nothing of their own minuteness, abundance and friability, they do not easily come under observation. In fishes, some are more plain, while others, because of their minuteness, are more obscure; from a comparison of both, however, we account their probable progress to be as follows: All the fibres scattered through the cerebrum and cerebellum seem to have their egress from the trunk of the medulla spinalis contained within the skull as from a notable collection of fibres; for from the four reflected crura of the medulla they are ramified hither and thither until their ramified terminations end in the cortex. In the cerebellum their progress is plainer; for the fibres are there drawn into the form of a tree in whose extreme branches and leaves as it were, the cortex is beautifully arranged,—but separated from the neighboring parts, so that the appearance is as of independent leaves. But in the cerebrum the roof or arch of the ventricles consists of fibres inclined towards the sides and built up into an arch (*fornix*). . . . From these and other fibres drawn from the posterior region of the cerebrum is built up the corpus callosum. . . . These fibres of the cerebrum are long drawn out. They are not parallel, but repeatedly meet each other; and we see them gathered together into a fascicle, then again separated, and afterward riding over other lateral fibres, so that they present the appearance of a loose network. This is best observed in the shark or dogfish. (pp. 114, 116-7, *De Cerebro.*) [*Fib.* 80, 58, 127, 131.]

Whether these fibrous bodies are hollow, or at any rate, whether, when gathered into a fascicle, they transmit a peculiar juice through the resultant little pores and interstices into the nerves continued therefrom, is a matter that would require long investigation. It is a problem that vexes the cleverest men of the age. After Fortius, the indefatigable Bacchius, and the famous English School have propagated through the hollow nerves, a nervous juice from the brain, and have contended for their position with remarkable arguments. And since, by reason of the smallness, softness and other like impossibilities in the cerebral fibril, we cannot use ligatures and the like, nor can our senses see the cavities, therefore there is room only for conjecture. The extremity of the fibres of which the brain is made up seems to be no light argument in favor of the existence of a separate humor in the brain and which is propagated therefrom into the nerves. For in its last little heads or roots the fibre is immersed in the cortex through which are ramified an immense abundance of blood vessels. This enrooting is plainly visible in the corpus callosum, and most plainly in the cerebellum, where the medullary substance in its extremity resembles branching trees, as was first observed by Cortesius. . . . That the arteries carry a sanguineous serum, or something similar thereto; that this is separated in the substance of the cortex as in a filter, and at the same time is propagated into the nerves implanted therein like roots, is not opposed to reason. For when the order of nature is interrupted by reason of some diseased condition, we have very frequently observed an abundant collection of this serum floating in the ventricles, the substance of the cerebrum, and under the meninges. . . . Nor are there wanting blood vessels, by which indeed, the whole substance of the cerebrum is pervaded; for if we institute a comparison with the whole body, we shall find at least a third, if not a half, of the blood is carried into the head; and since, because of the smallness of the viscus, it would never be consumed there, it is extremely probable that a coagulable serum is filtered through the cerebral fibrils and from there is derived into the nerves which are their continuations; and that the rest of the blood is gathered up by the extremities of the accompanying veins and returns to the heart. . . . In the more perfect red-blooded animals the choroid plexus does not intimately embrace the white fibres of the ventricles, but is stretched out free and without insertion; so that the whole ramification of vessels is dispersed through the other or cineritious portion of the brain; as is plainly apparent in the ventricles and outer cerebral circuit of fishes where the netlike propagation of the vessels is so abundant that it almost covers the underlying cortex. . . . Thus we again have reason for thinking that, in its inmost structure, the cortex or the cineritious substance derives into the fibres a fluid which is expelled from the vessels. (pp. 117-8, *De Cerebro.*) [*Fib.* 142, 128, 137, 166, 171.]

22. Leeuwenhoek. First of all I undertook to examine those parts of the brain of a turkey-cock which are commonly termed the cortical. These parts are composed of extremely pellucid, crystalline, and, as appears to the observer, oily matter, which, because of its limpid and pellucid substance, ought more properly to be called the vitreous rather than the cortical substance of the brain. When I was separating this matter into its least particles, I at once noticed trickling from it a small quantity of a thin fluid or ichor abundantly beset with extremely small globules, thirty-six of which, I judged would not equal in size one of the globules that impart to the blood its red color. This trickling liquor, although it did not spread from the brain more than, perhaps, one-tenth part of a hair's breadth, was yet commingled with the little globules, as just stated. But I observed this fluid matter especially in the brains of turkey cocks which had been killed for some time. This experiment taught me that part of this liquor flows from certain small vessels; and, moreover, that many small vessels have perhaps degenerated into an aqueous matter. In addition to these small globules there were also many larger globules, six of which, I judged, would make one of our blood globules. . . . Moreover, scattered through this vitreous substance were certain clear and irregular globules, some of which were equal in size to one of our blood globules, while others were larger. Throughout this clear matter and these globules were scattered a great number of extremely minute blood vessels, and this in a portion of the cerebrum no larger than a moderate sized grain of sand. Many of these blood vessels were so small that, so far as the eye could discern, if one of the plano-oval particles in the round corpuscles of the blood which give to the blood of hens and other birds its red color, were divided into fifty parts, not even so could one of them be carried through the cavity of these little blood vessels. . . . And yet, although these vessels were so exceedingly

minute, their color proved that they contained the matter which gives the blood its scarlet color; and unless I had observed one of these plano-oval blood particles on another occasion, it would have been impossible for me to have recognized these little vessels as sanguiniferous ducts. It is thus manifest that the red matter still impresses on them something of color. I became the more certain of this when I observed the presence of other blood vessels somewhat larger and of a deeper color verging to red. These exquisitely fine blood vessels, when laid over each other three or four deep, without any other interjacent material, were likewise distinguished by their red color. Noticing and seeing these things I believed more firmly than before that these plano-oval particles of the blood which make it red, are resolved when they arrive at veins of such smallness that they could never enter them unless first dissolved and broken up. In this way I was confirmed in the opinion as to the origin of the brownish color bestowed upon the cortical part of the cerebrum and wherein it differs from the white part which is called the medullary, namely, first, because its matter consists for the most part of these same pellucid particles so closely joined together as to produce a vitreous or aqueous pellucidity; and second, because the brownish color is heightened by the passage through it of many minute blood vessels. . . . We also observed that in many places these cortical parts of the cerebrum penetrate deeply into the medullary parts where they are immersed; but when we gently separate the deeper parts of the cortex, lying in the middle region of the cerebrum, from the medullary parts, we see between them so great a number of little blood vessels, as to make an entire membrane. . . . In addition to these fine blood vessels, there are, in the cerebrum, still other vessels of such fineness, that, in my judgment, no round corpuscle could permeate them, even if it were divided into more than a thousand parts. I say nothing here about blood vessels which equal or excel the thickness of a hair of our head; these also insinuate themselves in great number into the medullary parts. and are frequently divided into branches. (*De Structure Cerebri,* in *Arcana Naturæ Detecta,* Lugd. Batav., 1708, pp. 30-3.) [*Fib.* 58, 197, 297, 129, 199, 128, 166.]

23. Turning then to the medullary parts of the cerebrum, I there happened upon certain irregular globules of different sizes,—some of them equal to or even exceeding the size of one of our blood globules,—which, so far as the eye could judge, consisted for the most part of a thin, translucent, and oily matter. These globules are found in the medullary part of the cerebrum (especially in the place where the dorsal medulla commences), in such abundance that they seem to constitute the greater part of the cerebrum. This vast number of translucent globules is what causes the white color. . . . These irregular globules were so closely united to each other, that when I saw any of them, either in small groups or alone, and tried to separate them, some of

them suffered an extension twice as great as their length would seem to admit of; and they appeared to me to be woven together by threads, after the manner of a net. Having turned my attention to these globules, I began to consider as to whether the minute blood vessels emerging from the cortical parts of the cerebrum are not again dispersed into fine twigs of the same kind; and whether many of these twigs do not, as it were, embrace these globules or yield to the globules; just as we see, in certain large trees, the small horizontal vessels to yield to the ascending vessels and to embrace, as it were, almost the half of their circumference. This my opinion,—that many of the irregular globules were surrounded by vessels,—was strengthened when I saw that many of the above mentioned vessels were clear in the middle, and carried at both sides a somewhat brownish appearance; and still more when I found, lying in the ruptured globules, many fine fibrous parts, which, as far as appears, are vessels. Moreover, when looking at the medullary parts of the cerebrum it often appeared to me as if I were looking at a fishing net, the threads or cords of which could be easily stretched; and that between each aperture of the net there lay a somewhat flexible piliform body,—which body was changed to a round or longish oval according as the net was pulled this way or that. I compare the small vessels of the medullary substance to the net, and its irregular globules to the piliform or globular body. The remaining medullary parts consisted of an infinite number of most minute globules, and of a clear thin matter. I conjectured that the latter had emanated from the ruptured vessels; also that certain vessels had flowed together into an aqueous matter. (pp. 33-4.) [*Fib.* 130, 131, 297, 319.]

24. Proceeding with my researches I took the head of a sheep, and on examining its brain, I likewise found in the cortical parts a vast number of the most delicate blood vessels, wherein, as I recognized, was contained the substance that gives the blood its red color; which vessels, therefore, also give a brownish color to the cortical parts. I have often seen this incomprehensible multitude of exquisitely minute blood vessels with my own eyes; and I saw almost every single vessel again splitting into lesser branches. Moreover, I noted a great number of globules one-sixth the size of the red blood globule,—which globules I judged to be blood escaped from the vessels by reason of their rupture; and that when contained in the more ample vessels, six of these globules would constitute one blood globule. I imagined that these globules, which are a sixth part of one perfect globule, when meeting vessels so narrow that passage would be denied them, must necessarily be divided into lesser parts, and that the vessels in question must be devoid of color. But that I may more perfectly place before the eyes the incomprehensible fineness of the blood vessels found in the brain, I think it well to reduce their thickness to a calculation by comparing them with a grain of sand as measured by the eye. I take it for granted that

those perfect globules which impart the redness to our blood, are of such size that one hundred of them placed side by side in a straight line, would not equal the thickness of a little grain of sand; hence it follows that a million globules of the blood would equal one coarse grain of sand. I now observe blood vessels in the brains, in respect to which I am positive that if one globule of the blood were divided into sixty-four parts not one of these parts would be able to traverse any of the little vessels; for if I put the diameter of these vessels as 1, and the axis of the blood globule as 4, then it would mean that even if a grain of sand were divided into sixty-four thousand parts still it could not enter the minute blood vessels of the brain, especially if the minute particles of the blood were not flexible but rigid. I nevertheless think that this kind of minute blood particle always enjoys flexibility like those blood globules which have arrived at perfect maturity. . . . I attentively examined with eyes and mind, the white or medullary parts of the cerebrum, and especially those that tend towards the beginning of the dorsal medulla, and, as I judge, I there found what I had not been able to see in the brain of the turkey cock, namely, what appeared to the eye to be oily globules, large and translucent as it were, surrounded by, or lying in, an ineffable multitude of the most delicate little rectiform vessels or lines, mingled with a number of coarser vessels; which latter took a straight course, and were remarkable for their pellucidity. (pp. 34-6.) [*Fib.* 128, 199, 200, 130.]

25. In my scrutiny of the cortical parts of the brain of an ox I have often thought that I could see and observe that the vitreous and highly pellucid matter which constitutes the greater part of the cortical matter of the cerebrum, consists of nothing but extremely fine lines or vessels, all joined together in the closest manner. . . . In all my observations, enumerated in these pages, I pass by without mention the innumerable blood vessels running through the cerebrum, which can be seen in the dissected brain with the naked eye; for they are like entire rivers when compared with the little vessels previously discovered and laid bare by me; which latter must be esteemed as the merest rivulets, brooks and rills. I also examined the vitreous parts, called the cortex, of the brain of sparrows immediately after I had killed the latter. In these I noticed small blood vessels of every kind just as clearly and distinctly as I had observed them in the brains of the ox and sheep; nay, all the other parts of the sparrow's brain have no difference in size worth speaking of when compared with the brain of the ox. . . . When, with the utmost accuracy I examine the vitreous substance, it seems to me to consist of nothing else than an incomprehensible multitude of minutest vessels, so closely adjacent to each other as, by their pellucidity, to resemble a vitreous substance when seen through the microscope; and this was more clearly apparent to me in the small

brain of a sparrow than in the large brain of an ox. . . . The minute vessels that in part constitute the vitreous substance are so small that no moderate sized particle of sand could pass through them unless it were first divided into many thousands of myriads. . . . The other parts of the white brain of the sparrow did not differ from the white parts of the brain of the ox, sheep and turkey cock, except that the transparent oily globules, which were surrounded as it were, by certain vessels, were by no means so large in the ox. . . . Reflecting on the situation and figure of the medullary brain, they seem to me to be fabricated in order that they may derive to the dorsal medulla the blood that has been prepared and elaborated in the innumerable minute vessels which pass through the vitreous parts of the brain; and also that many of the small arteries found in the brain seem to be for the purpose merely of pouring the blood into the brain without making any return of it to the veins, and this, in order that a new and ever constant matter may be procured for the dorsal medulla and consequently for the nerves. (pp. 36-40.) [*Fib.* 128, 137.]

26. When I contemplated under the microscope the brain of a codfish, I saw, and not without admiration, many somewhat long and extremely fine fibrils; of these by far the greatest part of the cerebrum is woven; and they were extended, not towards the centre of the cerebrum, but rather towards its other extremity. Not content with this observation, I endeavored, with what reason I could, to find out whether the little parts which I have spoken of as being very fine and somewhat longish, are interiorly pervious with hollow passages. At last, after some days, I distinctly recognized those passages or cavities with my own eyes, and this not once, but at least fifty times. Moreover, I saw that the fibrils were of two kinds. One kind was equal in thickness to the little vessels which form the principal texture of the nerves; but these fibrils were very few in number as compared with the fibrils of the other kind which were finer. I was not a little delighted at this discovery, for I had not hoped that the vessels referred to would offer themselves so clearly and plainly to my sight, since the vessels were of such fineness as to be beyond the belief of one who has not himself seen them. I have often had the brain of a codfish dried out, and when I examined it in this condition I never failed to find that these vessels of which I have spoken, remained entire and uninjured. (Epistolæ Physiologicæ, *Epistola*, xlv, pp. 433-4.) [*Fib.* 142, 129.]

27. I have often observed, and not without delight, that the structure of the nerve consists of extremely small vessels of inexplicable fineness; and that these, running lengthwise, compose the nerves. The diameter of such a vessel when compared to its cavity exceeds the latter threefold. In one respect I was unfortunate in this business, namely, in that I was unable to exhibit these cavities to the sight of others; for as soon as I moved them to my eyes for the purpose of examination, in less than

a minute they suddenly collapsed by drying out, so that the remarkable sight wholly vanished beyond the possibility of being restored by any industry. Nor did I see merely the borders of these vessels,—vessels which seem to be gathered together to the number of some hundreds in order to make up a single nerve,—but in some of them I also recognized the cavities, and this as distinctly as though we had perforated a piece of paper in a number of places with a very fine needle, and saw the sun shining through the holes. And although this opening was so minute, yet I have seen living animalcules swimming in drops of water which could freely move and swim through that opening. In a word, the minuteness of some of the things seen by me seems to transcend all belief. (Epist. xxxii, pp. 310-1.) [*Fib.* 142, 188.]

28. I afterwards cut a nerve [taken from the medulla spinalis of a cow or sheep] into slices or transverse sections little or no thicker than a hair of the beard. After duly moistening these slices, I placed them in a glass goblet to dry. Examining them after they were dry, I found in them many little prominences. The explanation of this seems to be that a nervule of this kind is made up of many little vessels, and when these vessels are contracted by cutting of the nervule, such humor as they contain is squeezed out and produces bulgings that present the appearance of little eminences. It has also frequently happened that when I was looking through the microscope at a thin slice of a nervule, —which before being dried had been washed by me in clear water, and, thus washed, had been put under the microscope,—I noticed a great host of certain minute particles swimming and floating through the water. It was my belief that these particles had issued from these very vessels; for the knife which I had used for cutting was of such fineness that it could shave a hair. (ib. p. 311.) [*Fib.* 188.]

29. Although I could hardly give a delineation of a transverse section of a nerve so as to show it as it appeared to me, yet I can lay it before the artist as it is stretched lengthwise. A very minute portion of such a nerve is designated by ABCDEFG in Fig 1.* ABCDEF is the minute portion of the nerve itself, and AGF a little branch proceeding from it. In this portion of nerve I not only could recognize the little threads of which the nerve is composed and which perform the office of little vessels, but I also saw that the individual nerves were hollow or pervious with a cavity; nay, and I seemed to discern by my sight the very particles which were contained in these little vessels. In the case of a great many of these nervules, I had cut them into transverse sections with such accuracy, and had so moistened the sections, that not only could the artist recognize those parts or vessels with his own eyes, but we also saw, running through the little individual threads of which, as I had told him, the nerve was contextured, a little line,

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*The figures will be found at the end of the volume.

which, as a matter of fact, was nothing else than the hollow channel of the vessel, but compressed. We found the same appearance also in the case of blood vessels when the flesh had become dried. In Fig. 2 BCDEF is a nervule with its many vessels dissected transversely; the little lines in the individual vessels indicate the cavities. This nerve is partly surrounded by five other nerves, GGGGG; of these, however, I have had only the borders shown, together with the tunics which surround the vessels enclosed. BNC, CHID, EKLF, and AFM indicate fatty parts; and I have observed that a nervule of this kind is invariably surrounded with fatty parts on its every side,—though I believe that the nerves of a lean animal are so continuous with each other, that they are separated only by little membranes. . . . Extended through a certain part of this same nerve I saw seven nervules which were entirely devoid of fat.

I then cut the medulla spinalis in such way that I could recognize the parts extended through its length. I have had a small portion of this medulla delineated, so far as nature can imitate art, in Fig. 3 where it is designated by the letters MNOP. Furthermore, I have repeatedly cut the same medulla transversely, and finally, with singular pleasure, I found its parts arranged in the exact order shown in Fig. 2 except that they appeared larger. Moreover, in many places I was able to distinguish the hollow passages of the vessels,—which I had cut transversely,—by the light of the sun. When I separated from the medulla spinalis the robust tunic with which it is engirded, I saw proceeding from the medulla spinalis very fine nervules in great abundance and in divers places. Some of them were so minute that frequently what I took to be a single nervule consisted of at least five nerves; and each of these five was of the same fineness as is designated by AFG in Fig. 1. As soon as these nervules have issued from the medulla spinalis they are at once inserted in the hard tunic which surrounds the medulla, being as it were conglutinated therewith; and when they again emerge they are seen to be increased in strength and to be clothed with a new tunic. In that place the nerves, which I had cut off close to their origin, were beset with abundant fat and were clothed with very strong membranes. (*ib.* pp. 312-314.) [*Fib.* 188, 142, 192, 206, 222.]

30. I separated the nerves from the medulla spinalis of a cow, or from its robust membrane, and, having dried some of them, I cut them transversely. I then noticed that their tunics were compacted of the same kind of stamens as those of which, as I have shown, the nerves consist. . . . I had a few nervules delineated in transverse section. Their border is shown in Fig. 4 by OPQRS. TVW indicates the cavity of the nerves. The figure also shows the stamens of which the nerve is contextured on the inside and which constitute its inner tunic. But many of the parts of the nervule either partly or wholly fell away; a small portion of these parts is shown in Fig. 5 by XYZ.

After these observations I never came across any spinal marrow in which I found any cavity. Whether this is to be ascribed to some little vein mounting over the nervules, or whether it must be referred to an imperfection in the nerve that was under observation, is a matter for enquiry. . . . I further examined the medulla spinalis of two cows, two sheep and one calf; and I closely observed with my eyes the nerves of this medulla, both in the place where they emerge from the medulla itself, and in the place where they again free themselves from its tunic. The latter nerves, which, in my examination I followed up even to the flesh, are shown in Fig. 2. Nor can I add anything to what I said above, except that, because I was investigating the hollow passages of the vessels, I may have perceived them more clearly than before. . . . I showed the things described above to a certain man through the microscope, and to my question, Did he not see the extremely minute vessels, and the foramina or openings of the vessels, he answered, Yes, I saw them at first sight. I then told him that what he had seen was a minute portion of those little open vessels of which the nerve is contextured. (*ib.* pp. 315, 317.) [*Fib.* 142, 188, 192.]

31. From a fascicle of nerve filaments taken from the shoulder of a fat yearling, I carefully cut out two filaments hardly thicker than a double thread such as is used by tailors, and no longer than a finger-joint. When I examined their other extremity I found nothing there except certain little parts mutually convoluted and contorted, and about as thick as a hair of the head. At various points lay two or three filaments mutually involved and complicated, with only a little interjacent matter. Seeing that I saw the same thing in three different filaments, I hesitated in doubt, being unable to bring to mind the probable cause of this convolution, although I had no doubt that the filaments used in this examination were truly nerves. I therefore proceeded to examine these nervules, or what appeared to be fibres or filaments of nervules. in various places; and I observed that at the other extremity these same nervules were arranged in the most compounded and close fitting order, and that they split up into a great luxuriance of branches or lesser nervules. Moreover, I saw that the single nervules, all of which were covered with their own little membranes, consisted of the most minute vessels. Indeed, one nervule equal to about three diameters of a hair of the beard, was furnished, as I judged, with at least a thousand vessels. (*Epist.* xxxvi, pp. 355-6.) [*Fib.* 258.]

32. Moreover, in the tunics which, as it appeared, proximately invested the nervules, I saw still other nervules, though so fine as to be no thicker than a hair of the beard. Adjacent to these fine nervules I saw another still finer. And although the nervules were so extremely small, yet my eye could distinguish in them vessels of the utmost minuteness with which they were abundantly furnished. And not long ago I counted sixteen vessels in one nervule which was thinner than a hair

of the beard. So I leave to the reader to infer how very minute these little vessels must be. In this same observation I found certain vessels, fine and minute beyond conception, which, being somewhat lucid, were seen to run transversely through the nervules; and unless I had perceived them on the slant, I should certainly never have recognized them. Some of them I noticed were forked, or divided into two little branches. Hence we must come to the same conclusion respecting the nervules as was expressed above and delineated in Figs. 4 and 5. But in order to impress upon the reader a more distinct notice of the little vessels of which, for the most part, the nerves are contextured, I show a small portion of a transverse section as seen through the microscope; it is indicated in Fig. 6 by ABCDEFG. The artist has shown the vessels as accurately as he could, though I think they were woven in the nerve more thickly and densely than is shown. As regards HIKL, I deemed it unnecessary to have the artist continue the drawing. When these parts of the nervules became at rest they lay very closely pressed together; but I had not cut them until they had dried out; and after the dissection and just before putting them under the microscope, I had again moistened them; and so it happened that in the process of drying they were pulled apart and stood further from each other than the neighboring parts. In another place, moreover, I saw a congeries of nervules which were twice as fine, and even finer, than the nervules F and B. (*ib.* pp. 357-8.) [*Fib.* 188, 192, 240, 174.]

33. Of vessels of this kind, as I have before observed, do nerve filaments or fibrils for the most part consist. But those fibrils, of which, as parts, the nerve is made up, are clothed with a certain mater for which I see no more suitable name than little membrane. Thus in this respect, the fibrils are in like condition as the tendons and the fleshy fibrils, these also being involved each in its own little membrane. And although I had no doubt that these nerve fibrils, howsoever fine they might be, were so formed as to be accommodated to the making of contractions and extensions (in order that they may be extended and contracted with the tendons and fleshy fibrils), nevertheless I wished to investigate this formation and see it with my own eyes. I therefore made longitudinal sections of various filaments of little nerves, and by aid of the microscope I had one of them delineated, as shown in Fig. 7, where it is marked MNOP. In this figure the vessels which serve for carrying down the juices of the nerves, so far as they are extended lengthwise, are seen to be convoluted into spirals or gyres. It must be supposed, however, that in every extension of the nerve these parts stretch their gyres out into a straight line. By MN and OP is designated the tunic which, as I have shown, is surrounded by its several nerves. (*ib.* pp. 358-9.) [*Fib.* 209, 258, 188, 192.]

34. What made me wonder, was, that, although I handled the parts of the cerebrum and medulla spinalis in the most careful and gentle

way, yet, under the microscope they appeared in such confused order and as though lacerated. But, thought I, these parts which now appear so twisted and unordered, had, in the living animal, been most beautifully and harmoniously ordered and joined together; but, with death, the soft structure of the medulla spinalis and cerebrum soon dissolves and flows apart; so that nothing certain could be concluded from that disorder which met my eyes; and I suspected the highly fine matter which I saw contained in the vessels of the cerebrum, to be nothing else than the coagulated particles resulting from the said resolution of the cerebrum. . . . I took two fascicles of nerves, and also some single nerve filaments from the medulla spinalis of a fat calf of about eight weeks old; for I wanted to see whether I could here find the narrow passages or cavities of the nerves. But I saw those passages not once only but many times,—a fact that gave me no little delight. One of the nerves used in this observation was a capillary nervule in which I counted, issuing from it, about twenty nerves of varying thicknesses. (*ib.* pp. 354-5.) [*Fib.* 142, 188.]

35. Examining for a second time a tendon taken, if I remember right, from a sheep's thigh, I noticed that the individual filaments or fibrils, which are extended lengthwise in the nerve, were so many vessels; but their hollow passages were often so compressed that in most of the fibrils none but closed passages could be discerned, although I was certain that all the fibrils were hollow or pervious. When the dissected parts of the tendon had been dried out I saw daylight shining through certain extremely minute passages. . . . Whenever I made a longitudinal section of a nerve I found it composed of longish filaments not unlike the little membranes which disperse themselves through the fleshy fibril, and which we find to be composed of the same kind of filaments. Nor, so far as I remember, have I ever made a transverse section of a nerve immersed in fleshy fibrils, although I have dissected innumerable fleshy fibrils and examined them under the microscope. But now, when carrying on various experiments with the aid of the microscope, I find under transversely dissected portions of a certain tendon, four nervules in close proximity to each other. These nervules are contiguous to the tunic of the tendon and each is about four times as thick as a hair of the beard. I distinctly saw that these nerves were hollow, like vessels, indeed they were cut into such minute little parts that I saw daylight shining through the apertures of some of the nervules. (*Epist.* xlvi, pp. 438-440.) [*Fib.* 188.]

36. When I set the structure of a pig's brain before my eyes, I had no difficulty in concluding that there must be a certain connection between the blood vessels and the particles of the brain, in order that the latter may be preserved, and may maintain their vitality by a perpetual inflow of blood; for in the bodies of animals where this is lacking, corruption must necessarily set in. That I might show some specimen

of these parts of the brain as accurately as possible, I selected the three best of my specimens and have had them delineated. In Fig. 8, ABCDEFGHIK designates an extremely minute portion of a pig's brain,—the particle BCDEF lying quite close to the meninx. AB, KC, ID, HE and GF, designate blood vessels which, immersing themselves more deeply into the cerebrum, escaped the sight; for the few and scattered blood globules which flow through them have not enough redness to make the vessels visible. Those particles that are interjected lengthwise between the blood vessels, and are, as it were, continued from them, we have rightly called fibrils of the cerebrum. These fibrils which have hitherto escaped my sight, are shown as cut, not straight across, but obliquely. In the same figure, ML denotes the ruptured particles of the above mentioned fibril. (*Epist.* xxxiv, pp. 330-1.) [*Fib.* 128, 129, 169, 173.]

37. In Fig. 9 the letters NOPQRS denote only a very small part of what we saw through the microscope; and it is delineated merely to exhibit to the reader the membrane, PQR which covers the cerebrum. The artery, NQ, seen in the middle of the figure, to which, on both sides, are joined fibrils of the cerebrum, is much thicker in the middle than at the extremities N or Q. The reason is, because the fibrils seen between NOP and NSR have so contracted or shrunken, that they have torn the artery; the middle portion of the latter, therefore, bulging to both sides, is necessarily thicker. Moreover, I placed under the microscope a minute portion of these fibrils of the cerebrum of which I had happily succeeded in making a longitudinal section. They are shown in Fig. 10, by ABCDEF. These fibrils exhibit to the sight four of their sides; indeed at one time I saw a fibril furnished with six sides. Hence follows the conclusion that one fibril consists of a number of fibrils. The fibrils shown in the figure were not taken from the neighborhood of the meninges, but from about the very centre of the cerebrum, and they consist of such minute particles, that you cannot recognize any shape in them. These cerebral fibres are, I suppose, covered with delicate little membranes, which because of their extreme minuteness never bare themselves to our sight. But unless we suppose their existence, how can we account for the separation or distinction between the fibrils which our eyes behold? This minute portion of the cerebrum was so shrunken, that in two places, BG and BH, the cerebral fibrils were ruptured. I therefore conjecture that those fibrils had been connected with each other by little membranes. A second rupture of the fibrils is seen in the same figure at IK and IL, where we see fibrils connected with the fibril I, and, above KL, with other fibrils also. What we see in the neighborhood of A and F are particles which lie enclosed in the cerebral fibrils and which have been laid bare by the scalpel, or by the incisions of the scalpel. When we see the fibrils of the cerebrum disposed in this manner, and when, at the same time, we

contemplate the fibrils shown in Figs. 8 and 9, we must consider it as established that the blood vessels delineated in these figures were cut lengthwise exactly along the line of their channel, and that the cerebral fibrils were cut across obliquely, so that to our eyes the latter appear incomplete. If now we reflect on the softness of the particles of which the cerebrum is contextured, and on the necessarily fragile nature of the parts that clothe the cerebral fibrils, we can readily imagine how that these parts would never become visible to human eyes. . . . But the above mentioned fibrils of the cerebrum, though conjoined with blood vessels in the manner just mentioned, and receiving from them their increase and nourishment, are yet by no means offshoots of these vessels, for I hold that these fibrils are not posterior in origin to vessels. (*ib.* pp. 331-3.) [*Fib.* 129, 169, 170, 177, 173.]

38. When I again secured the brain of a pig, I at once removed the investing membrane, and placed some parts of the cerebrum under the microscope. Examining them with the closest attention, I found fibrils of the cerebrum contiguous to the meninx; but as far as I was able to distinguish by sight, they showed a preference for the round rather than the quadrangular figure. . . . And although, during late years, I have examined the brains of many animals, what I have just explained has never before met my eyes. After the brain had been dried out I was not able to distinguish the parts just mentioned; but when I placed before the microscope fibrils of the cerebrum that had been dissected transversely I was able to discern their borders; still it was necessary to fix the gaze so intently that unless I had known that it was these fibrils that I had dissected, I would never have been able to pick them out. I have often made longitudinal sections of the fibrils of the cerebrum where they are adjacent to the meninx, and finally, I was fortunate enough to successfully place them so dissected under the microscope without a break. I at once had them drawn, and they are shown in Fig. 11, by ABCDEF, CDE denoting the membrane investing the cerebrum. Where these cerebral fibrils are stretched lengthwise, they are rendered uneven by a number of rugosities, which the artist has imitated as accurately as he was able. The gap between A and D is caused solely by this corrugation, whereby some of the fibrils are drawn apart from each other. I afterwards tried to so separate the fibrils of the cerebrum from each other as to see both their thickness and their breadth; but, in the process, they were, in part, broken into minute fragments. I placed the largest of these fragments, although it also was broken, under a higher powered microscope, and, in Fig. 12, I have had it designated by GHIKLMN. The rupture of this portion is seen in two places, namely, HI and KL. The blackish color, marked MN, denotes the thickness of the fibril. As regards the flexures seen in the same place, I am unable to say whether it was I who made them, or whether they were caused by the pressure of adjacent parts. I take

it that these fibrils of the cerebrum are easily four times thicker than the flesh fibrils of the ox. Moreover, I placed under the microscope an extremely fine particle of the cerebrum, in which appeared an incredible multitude of blood vessels cut transversely and at right angles; indeed, all the parts designated in Fig. 13 by the letters OPRSTVW, even to the very dots, are nothing but blood vessels. Y and Z designate two larger vessels, containing clotted blood; here also it can be seen that the tunics of the veins have been partly torn away from the cerebrum. STVWX indicates the parts of the cerebrum which were ruptured in the process of drying. Through all the blood vessels shown in Fig. 13, which occupy a space no larger than a grain of coarse sand, there is no doubt that the blood runs and circulates with a perpetual flow and reflow. (*ib.* pp. 334-6.) [*Fib.* 129, 177, 128, 169.]

39. I have not unfrequently found nerves which I had dissected transversely, to be divided by the finest membranes into three, four and also more nervules; and this in such way that the whole collection of nervules, that is, the large nerve itself is girt by a more robust membrane. When I placed under the microscope a nervule no thicker than a swine's bristle and of a somewhat flat shape, I judged it to be compacted of at least thirty nervules; and this in such way that each individual lesser nervule was girt with its own proper membrane. Later I came upon a much finer nervule which I judged to consist of seven or eight nervules all enclosed in their own little membranes. . . . I once noticed a little vein passing transversely through an extremely minute nerve and giving off a great number of shoots. Not infrequently also I have seen an arteriole running through the length of a nerve and scattering into branches filled with blood. In some nerves I have seen blood vessels of such fineness that the blood in them was not tinged with red, nor could the vessels themselves be discerned except by the most intent gaze. . . . The extremely minute vessels, of which, for the most part, the nerve is contextured, are also clothed with their own little tunics, not unlike the veins and arteries; but these little tunics are not conglutinated or coalescent with each other; but as I have often observed, each nervule is assigned its own separate place, and is covered about with its own little membrane, exactly as we have declared with respect to the fibrils of fishes and to the fleshy fibrils, namely, that they are all invested with their own little membranes. . . . Moreover, I observed that those parts of the nerves which performed to them the office of vessels, were made up of an incredible multitude of longish and extremely fine little parts; and, just as tendons with their flesh fibrils are so formed that their parts are well adapted for extension and contraction, so also, as I found, these longish parts or filaments of the nerves are formed after the same plan. For when I separated the stamens from each other I saw them convoluted and curved into spirals after the manner of snakes. (*Epist.* xxxvi, pp. 350-3.) [*Fib.* 174, 240, 209, 208, 258.]

40. I noticed fibrils which were joined together at one point, and then, at another, diverged from each other, and a little later again united; and if I remember right I have observed similar conjunctions in the muscles of a heart taken from a certain animal. On the basis of this observation I reasoned, that the fleshy fibrils of the heart, being affixed to no tendons so far as the eye can follow them, must necessarily be conjoined and connected with each other, and, being thus assisted by mutual forces, are equal to carrying on the work for which they are destined; I reasoned then that the same thing must be true of the cerebrum. In order to make this clear as far as possible, I have had delineated an extremely minute particle of the cerebrum as seen under the microscope. It is shown in Fig. 14 by ABCDEF, where CD are fibrils of the cerebrum, disjoined from each other, then coming together, and again diverging, but once more returning to the union at I, and still again at H. I have observed these alternations of conjunction and secession also in other places. Moreover, I placed under the microscope a ruptured particle of a cerebrum, designated by KLMNOPQR in Fig. 15, where we see two fibrils digressing from each other at the letter N, and at once associating with other fibrils. Such consociations of fibrils can also be seen in other fibres. (*Epist.* xxxiv, pp. 338-9.) [*Fib.* 131, 197.]

41. I have had delineated a minute particle of the tendon of a sheep, denoted in Fig. 16 by ABCDEFGHI, and showing what a number of septa are contained within this little portion of tendon. These septa consist of longish particles, which in their turn are woven of other longish particles but finer. These parts which I call septa are separated from each other by membranes, and, seeing that the larger tendon is covered with a membrane, each one of these may be called a tendon; but as soon as we come to that part of the tendon where it is to be inserted into the muscle, it is easily divided into a thousand tendons. The several septa shown in the figure recede from each other, and after the recession the individual parts are invested with a fine little membrane. . . . I recently found that not only are tendons invested by a strong membrane, but that this membrane gives rise to little branches, and that these, luxuriating into new branches, form those septa, of which we have just spoken; and that these again are dispersed into lesser tendons. The membrane covering the larger tendon is denoted in the figure by IABC. The figure also shows what a number of branches, springing from the larger membrane, insinuate themselves into the tendon and distribute it into lesser tendons. (*Epist.* xxxiii, pp. 319, 320, 322-3.) [*Fib.* 222.]

42. I then placed under the microscope a minute portion of a tendon cut straight or longitudinally, and I clearly recognized that the tendon was compacted of six or eight smaller tendons. In each of these tendons the form was a spiral one,—a form which, in the motion of

bodies, seems to be especially adapted for contraction and extension. Furthermore, I have had delineated a minute tendon which was adjacent to the outside of the tendon just mentioned. It is shown in Fig. 17 by the letters KL. Here may be seen the spiral parts, or parts revolving and rotating in a gyre, and which lie on the tendon just like the thread or edge on a screw. And indeed nothing can be imagined more suitable for the exercise of contractions or extensions than this spiral figure and rotable nature. Nor is that spiral figure and that form of circumvolutionary parts confined only to tendons, for neither is it wanting in the fleshy fibrils which are annexed to the tendons. . . . In this figure between K and L are also shown the parts of which the little tendon is contextured,—although I could never have distinguished these minute parts unless they had previously been separated. But after they had been separated, we then recognized in them those small and snake-like spirals which they had had before the separation when they had been collected into a minute tendon. If we see these things in the larger animals, we must certainly hold that the same things exist also in the smallest animalcules. As regards myself,—in the legs of the flea I can most distinctly recognize not only tendons and fibrils, but also the spiral and volutionary contractions of the fibrils, which, as I can clearly discern, is also not wanting in the muscles of the flea. In flesh taken from the legs of a wild bee I not only observed spiral extensions and contractions, but I also found that the fibrils of the bee are but little more slender than those of the ox. (*Ib.* pp. 323-4.) [*Fib.* 258.]

43. When some oysters were lately brought to the table certain of them held their shells so tightly closed, that although the knife was forced between them it would hardly pierce; indeed it had to be pushed with considerable force, and by this I broke the tendon which held the shells so tightly closed. This tendon,—although it was exceedingly minute stretched lengthwise,—I afterwards cut into a number of very thin slices which I put under the microscope and carefully examined. I found that they differed considerably from the tendons of other animals, both in texture and in operation. The contractions in the tendons of the oyster are not effected by circumvolutions as is the case in the tendons of animals, but by folding. It is as though we took a piece of paper and, folding it from both sides, attached one end to the upper shell and the other to the lower. When the oyster very slightly opens its shell the folds of the tendon are somewhat unfolded or unrolled; but when the shells are again closed the folds subside and approach each other. For a better understanding of the structure of this tendon I have had a very small portion of it delineated in Fig. 18, where it is designated by MNOPQRSTV. In this figure we see a small and slender tendon contextured of many compacted fibrils. When I looked at the tendon more attentively and saw its manifold fibrils

colligated by membranes, I noticed that the fibrils so colligated made a little thread, and that from a number of these threads was formed a thicker thread. In the process of drying these threads or fascicles were separated from each other, as seen between NO, OP and PQ; O and Q designate the torn membranes by which the fascicles had been invested. (*Ib.* pp. 325-326.) [*Fib.* 188, 222.]

[44.] BOERHAAVE. (*Institutiones Medicæ.*) The arteries of the brain are interwoven in the pia mater in firm order, as in a base incredibly thin like a spider web. From every point of this meninx they send down, almost perpendicularly, little twigs, and these, by a process of anastomosis similar to what characterizes the arteries, are formed into, as it were, a membrane which, by its insinuation, makes the furrowed and deep gyres into which the exterior mass of the cerebrum and cerebellum is divided almost down to the medulla,—the furrows of the cerebellum, however, not being so deep as those of the cerebrum. These furrowed tracts, convoluted into the form of the intestines, may again be resolved into smaller and similar tracts all formed by the insinuation of the pia mater. They carry red vessels only on their outer surface and apply them to the matter which they enclose. The substance thus enclosed is for the most part never suffused with any red color, never admitting any sanguiniferous artery or vein; and what remains in the cerebrum and cerebellum after the latter have been injected with wax, macerated in water and freed by abrasion of every part not filled by the injection, appears as a congeries of vessels, like flock or down, minute, extremely soft and juicy, dissolving at the very least force, and turning into a pasty humor by mere suspension in plain water. (n. 236.) [*Fib.* 128, 137.]

45. The outer cineritious, soft, and more humid substance is called the cortex of the cerebrum and cerebellum. It everywhere closely invests the entire origin of the other substance, which is within, is extremely white, more solid, and less juicy, and is called the medulla of the cerebrum and cerebellum. It is clearly manifest, therefore, that the latter everywhere first arises from the former, both in the appendices, the ventricles, the crura, and the medulla oblongata. But in the interior of the medulla spinalis, on the other hand, is found a substance similar to the cortex, being in like manner wholly arterial; but it is here surrounded by the medullary substance; which is just the reverse of what obtains in the former case. In the cerebellum, these two substances are so conspicuous that the manner in which the medulla proceeds from the cortex, and the distinction between the two, their proportion, and fabric, can all be clearly discerned. It can also be seen that the cortex here is always harder and more yellowish than the cortex of the cerebrum. (n. 237-8.) [*Fib.* 127, 231.]

46. When Hippocrates, Wepfer and Malpighi compared the cortex of the brain, carefully examined, with the fabric of glands, having

found a similarity clear to the eyes, they took the cortex of the brain to be truly glandular. Malpighi declared that these glands,—angular and of an oval shape from the pressure of the neighboring glands, tortuously arranged, small,—connected with other glands, shortly constitute larger aggregations, and that from these again grow still larger aggregations, and that finally from the aggregate of these results a mass like the convoluted intestines, and from these masses the outer cortex. So that the last little branches of the carotid and vertebral arteriole here convoluted into the structure of a gland, exhale from their infinitude of tiny mouths a most subtle humor drawn from the blood, and instill it into their follicle to be conveyed therefrom into the emissary, the rest of the blood being returned by the little veins into the sinuses. Malpighi's opinion is favored by the eye; the microscope; the boiled brain dividing up into molecules like glands; the wiping off of ink that has been poured over the cortex, thus showing up the prominent little masses distinguished by clefts; the hardening of a diseased brain into a stone like a mulberry;* its corruption, when contused, into a kind of glandular fungus rising up from the opening of the fractured cranium; the change of the parts that constitute the external brain into evident spherules as a result of cerebral dropsy,—all these things prove that here is the same equipment, though more subtle, as elsewhere in glands. But whether the ultimate little twig becomes the very origin of the fibrous substance of the cerebrum by direct continuation, as would appear from Ruysch's observations, is not made certain by any sufficiently strong argument. While, by reason of their fineness these ultimate twigs vanish from the keenness of our sight, yet when they are filled to the uttermost by Ruysch's method the medulla never reddens but remains perfectly white. Nevertheless, for many grave reasons this opinion seems to be extremely probable. These ultimate little branches, or these least glandular follicles, send out delicate fibres,—white, compact, the unition of which forms the hard (*callosum*) and medullary body whereon the cortex rests and whereto it is connected,—which become more and more consistent both in the cerebrum and in the cerebellum. So that there is never an end of the cortical substance where is not found at the same time a beginning of the hard (*callosum*) or medullary body. The cortical machine so accommodates itself to the medullary body that it not only adheres extrinsically to the cerebrum and cerebellum, but also accompanies the outermost appendages of the corpus callosum, the ventricles at the beginning of the medulla spinalis, and the long course of the latter outside the brain,—but in such way that the cortex is here laid up within the medullary portion, a median sinus being thus intercepted, and is irrigated with numerous arterial vessels. Therefore, in every part of the encephalon, where there are least invisible arterioles, accompanied, as we must necessarily admit, by invisible little veins, there we find this cortical mass; and this, not only in the external surface but also in the recesses, circumvolutions, interstices, and appendages. (n. 263-6, 267, 268.) [*Fib.* 128, 137, 91, 213, 231.]

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*See n. 19.

47. Since something of the medullary substance arises from every point of the cortex, therefore, at the commencement of its origin it must be extremely tender; joined with other like substances it gradually thickens, and, becoming at last visible, constitutes the medulla of the cerebrum, the corpus callosum, the crura of the medulla oblongata,† the tuberosities; and also the medulla of the cerebellum, and its productions into the medulla of the cerebrum; which latter, receiving these contributions, is extended into the pyramidal and olivary bodies and into the medulla spinalis as far as the second lumbar vertebra, whence it goes off into nerves distinguished from each other by coverings taken from the pia mater and which in their mass resemble a horse's tail. From this medullary mass within the cranium and within the vertebral sheath arise all nerves whatsoever. But that these primary filaments are separate and distinct from each other, although when united they seem to form one compact body, is clearly evident to anyone who considers: 1. Their origin, elements, and progression while they are still single. 2. The raw or boiled brains of fishes, hares, sheep, and oxen, wherein deep-set cylindrical fibrils clearly appear, laid side by side like the teeth of a comb. 3. The delicate blood vessels set between the fibrils and making manifest division. 4. The cortex interposed in the centre of the medulla spinalis surrounded by medullary substance. 5. The white fibres scattered through the midst of the cortex found in the posterior part of the medulla spinalis while it is still within the cranium, and at the sides of its commencement, also within the cranium, and, best of all, in the appendages of the corpus callosum and in the cerebellum. 6. The gathering and dispersion of the medullary fibres into the medulla oblongata and from there into the nerves. (n. 269, 270.) [*Fib.* 91, 213, 231.]

48. We may well believe that the medullary fibrils of the cerebellum —a body whose medulla gives forth no nerve—ascend upwards from a situation beneath the commissure toward the anterior parts of the medulla oblongata and there give to the nerves rising from the cerebral medulla, certain fibrils of the cerebellum, the distinction in origin, progress, and office being always accurately preserved. This will be manifest to everyone who contemplates the different insertions of the medulla of the cerebellum into the medulla oblongata of the cerebrum the thalami of the optic nerves, the medulla oblongata and its crura‡

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†The corpora striata.

‡The peduncles of the cerebrum.

and the mass thence resulting; and who also considers the fact that the spinal nerve returns from the vertebral sheath into the cranium in order that it may there join itself to the nerve of the eighth pair. The other fibres of the cerebellum are so mingled with the fibres of the cerebrum that there is perhaps hardly a part of the whole medulla oblongata and medulla spinalis, where fibres of the cerebrum are not found commingled with those of the cerebellum; so that in the composition of the body of the nerve, they are certainly everywhere concurrent for the production of wholly diverse and distinct effects. (n. 273.) [*Fib.* 98, 231, 91.]

49. Whoever considers, 1. the nature of the cortex as set forth above, and the fact that the medullary fibrils arise from it in the most distinct way; 2. the similarity of this arrangement, with every other part of the body; 3. the vast abundance of the very finest, purest and most mobile arterial blood, undespoiled of its subtlest part, that is driven hither with great force by the neighboring heart; 4. the exquisitely fine fluid always and everywhere to be found by sight, touch, and especially by the microscope, within the medullary substance when dissected,—a fluid which in diseases of the injured brain, is often greatly augmented; 5. the fact that the veins return to the heart the blood which has been brought to the venous sinuses by veins from the pia mater and the cortex of the cerebrum and cerebellum; 6. the constant, ordered and proportioned increase, nourishment, propagation and return of these stamens from the first point of life to the last goal of life,—such a one must judge these fibres to be pervious little channels of the utmost fineness, that take up a humor, the most subtle of all in the human body, which, prepared and secreted in the wonderful fabric of the cortex and driven by force into these tubes, is collected from every point of the cortex into the medulla oblongata. (n. 274.) [*Fib.* 142, 197.]

50. If further, with attentive mind, one comprehends, 1, that the whole vascular medulla is expended on the constitution of nerve fibrils, yea, goes off into such fibrils by mere continuous extension; 2. that when the medulla of the cerebrum or cerebellum is compressed, cut, rotted, eaten away, every action accustomed to be done through the nerves arising therefrom, is at once abolished, even though the nerves continue unimpaired, and with membranes intact; 3. that the nerves, everywhere lax, pendulous, curved, retrogressive, oblique, yet execute motions and sensations with the utmost promptitude; 4. that, nevertheless, when compressed and constricted, the nerves, even though unimpaired, lose every faculty of motion and sensation in the parts that lie between the ligature and the last places to which those nerves are extended, their power between the point of ligature and the medulla of the cerebrum and cerebellum being unaffected,—he will most certainly conclude that the nerve fibrils assiduously receive the humor of the medulla, transmit it, and carry it down to every point of the whole

body by the most distinct paths; and that in this use alone do they entirely fulfill their office. (n. 284.) [*Fib.* 142, 197.]

51. Does it then seem wonderful to you that the eye cannot follow the presence and motion of this humor; that ligatures, wounds, punctures, suctions, air pumps, injections are of no avail to exhibit it before the eye; that by no skill can the cavities of the nerves be laid before the keenness of its vision? Truly, he who attempts such things with this intention, knows not the nature of these vessels and of the liquor itself. But he who, on this account, denies the existence, in these little vessels, of cavities that flee the sight and elude the skill, is surely ignorant of the rationale of our body in its origin, progress, operations, and excretions; and knows not the structure of insects, nor gives heed to the phenomena which so manifestly occur in plants. Therefore, also gross is that error which recognizes the thickish lymph that trickles from the cut nerves of an ox's tail, as that humor, which we have just described. . . . This humor, by reason of its perfect simplicity, mobility and volatility, we call the spirit of the nerves,—a spirit which is natural, vital and animal. (n. 289-291.) [*Fib.* 84, 142.]

[52.] RUYSCH. The ancient anatomists assert that the brain is a substance *sui generis* such as is found nowhere else in the whole body. . . . Hippocrates in his treatise on the Glands lib. iii, sec. 7, attributes glands to it and this doctrine has been reasserted by modern anatomists, among them being Malpighi, Bohn, Stockhammer and Vieussens, who have supported it with many experiments. But after injecting the smallest arteries with customary dexterity so that the very least branches, filled full, appeared like a mass of hair, we saw with the utmost clearness that the cortical substance consists of mere blood vessels, variously combined of the tiny arteries issuing from the inner surface of the pia mater, and presenting the appearance of moss or of a mass of hair. This mass of hair, so to speak, is nothing else than the drawn-out extremities of little blood vessels; and these, as I have also remarked when treating of the spleen, at their extremities, are seen to put on another nature and disposition; for they are so soft and liquid that unless filled with some injection they can hardly, if at all, be handled without danger of their dissolution,. (*Epistola* xii, pp. 16-8.) [*Fib.* 128, 137.]

[53.] Ruysch describes the pia mater of an infant as being so tender and subtle that hardly anything membranous was to be seen; yet it contained arteries in such great number that it seemed to consist almost wholly of little arteries,—a fact which cannot be demonstrated unless the arteries be filled with a wax injection; without which the pia mater seems much thicker, its thickness being contributed to by the empty vessels. "These arteries (says Ruysch) can hardly be intended merely for the nourishment and warmth of the pia mater, for this membrane is too fine to need so great an abundance of vessels." He therefore conjectures that the principal use of the membrane is to hold the blood vessels in their natural situation; and that the arteries, in their extremities, constitute the cortical substance. This is why there is so much difficulty in separating the pia mater from the cortical substance of a healthy brain. (*Thesaurus Anatomicus*[*] I, Asser. ii, n. 13; I. As. vi, n. 8; VIII, n. 18; III, n. 40, 68; V, n. 24; X, n. 17). He describes a portion of a pia mater with a part of the cortical substance annexed and which is seen quite plainly to consist of mere extremities of blood vessels. "These extremities become softer and softer, so that finally they may be dissolved into a pultaceous substance by the mere use of water. If, however, the cortical substance has been hardened it loses its soluble character and becomes lumpy." (*Thes. Anat.* I, As. iii, n. 19.) Ruysch also describes a portion of pia mater where the cortex is of a red color by reason of the injection of the arteries, while the medulla has remained white. (*ib.* X, n. 19; V, n. 45, 48.) In one case he so loosened the arterioles in an injected pia mater that it could be plainly seen that the cortex consists of mere blood vessels and not of glands (*ib.* X, n. 33, 17.) "Convinced by experience I now think that the cortex consists only of the ends of arterioles which have changed into another nature; that is, that the ends of the ultimate arterioles of the pia mater, changed into a new nature, are the cortex itself." (*Epist. ad Bohlium,* p. 10.) [*Fib.* 128, 137.]

In Table xiv Ruysch shows a portion of cortical substance suspended by a hair in liquid. The outermost arterial branches are seen to be so subtle as to become invisible except by the microscope and when injected with wax. They then present the appearance of a mass of hair. The figure also shows diversiform particles which are nothing else than the juicy extremities of arterioles which, although they are continuations of arteries, yet, by reason of their softness, are so set together, as to put on the appearance of a distinct and peculiar substance. (*Epist.* vii.) [*Fib.* 128, 137.]

[54.] The pia meninx insinuates itself between the interstices of the cerebrum and of the cerebellum; but it must not be thought that this insinuation is effected in the same way as that in which the omentum is let down among the convolutions of the intestines, or as a cloth is pushed into various hollows. By insinuations of this kind the length and breadth of the omentum or of the cloth is, of course, diminished; but this is by no means the case with the pia mater. This is clearly evident from the fact that after this membrane has been carefully separated from the cerebrum and cerebellum its size and extension is not increased, howsoever much it had insinuated itself into the windings, unless the connections made by means of the fibres and vessels be everywhere removed by the hand when lifting it. It seems to me, therefore, that this pia meninx sends down certain processes into all the furrows and windings in an almost similar way as the falciform process under the longitudinal sinus emerges from the duplicature of the dura mater; so that the whole pia mater produces as many processes as there are windings, and these not falciform in figure but winding in a serpentine course. In like manner the pia meninx is immersed into the interstices of the cerebellum with as many falciform processes as there are furrows or windings; and when it is taken off and separated it presents a very pleasing appearance of the cells of the white poppy. (*Epis.* vii.) He mentions having injected a portion of a human brain, but not so fully as to color the cortex. When this brain became as hard as soft cheese he broke it into pieces. One of the pieces, which he has preserved, shows how deeply the pia mater insinuates itself between the furrows of the cerebrum; therefore the cortex is made up of these arterioles disseminated throughout the pia mater, not only in the surface of the cerebrum but also between its furrows. (*Thes. Anat.* X, n. 28.) "Among all my discoveries within the past forty years stands out the discovery that the cortical substance of the brain is not glandular,—as anatomists have wrongly described and depicted it, and as they have asserted with assurance,—but is wholly vascular. (*ib.* VI, pp. 8-10.) Almost all the arteries with which the pia mater abounds tend downwards, in order that they may constitute the cortex; the ramifications of these arteries are so numerous as to excite the utmost admiration. (*ib.* VI, n. 79.) He describes a pia mater which he had preserved entire and almost uninjured. At its extremities the arteries were so wonderfully filled with his injection that their extremities represented a mossy covering of red vessels. In various places, moreover, the pia mater was rich with fat. (*ib.* V, n. 13.) In another pia mater that had been injected to the utmost, Ruysch saw fat scattered through various parts of the membrane. (*ib.* V, n. 13; VI, n. 23.) He has also seen fat in the duplicature of the pia mater. (*ib.* IX, n. 42.) [*Fib.* 172, 128, 137, 297, 197.]

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[*] The THESAURUS ANATOMICUS is a catalogue, with comments, of the various specimens preserved by Ruysch, mainly by use of the remarkable wax injection which he invented. The catalogue is listed according to shelves (Asser.). In Books I and II each shelf is numbered separately; but in the other books the numbering proceeds without interruption.

[55.] The knife is unsuited for the examination of the brain, because of the latter's softness; boiling in oil changes its substance; and these processes have persuaded some anatomists that the cortex is glandular. Rejecting their methods I betook myself to a new and better method, namely, the artificial filling of the blood vessels with a red waxy matter. When this is done the particles of the cortical substance must be taken off and suspended by a hair in some suitable liquor; then the hair must be seized by the fingers and the particle of cortical substance be thus moved up and down. By reason of the motion it then unfolds into an infinitude of little branches, fine as a mass of hair, but soft. I have devised this method not only with the cortex but also with many other parts of the body; without it, I think it impossible to find out their real nature. . . . It is objected that the color of the cortex is cineritious. I do not argue about this. I merely answer that it can be shown that in various places the extremities of the arterioles are changed without any intermediary substance into vessels of another nature. . . . If the cerebral arteries are injected with red wax the entire cortex is suffused with red, and this without any extravasation,—a sure sign that the cortex consists of the extremities of arteries. . . . I have never yet been able to show any venous extremities in the cortex. In our injection of the arteries I fill them gently and without vehemence; and if the whole cortex is affected with red without any visible filling of the veins, it seems likely that the superfluous part returns to the veins before the least arterial extremities are given off to constitute the cortex. (*Thes. Anat.* VI, n. 73, pp. 39-41.) [*Fib.* 128, 137.]

[56.] "Many modern anatomists perversely make several parts of the human body to be glandular, and according to these authors the choroid plexus is not free from glands. Desirous of knowing the genuine constitution of this plexus, I examined it by my method. Filling it with waxy injection and viewing it both with naked eye and under the microscope, I found it entirely devoid of glands. But they assert that the glands of the choroid plexus are so minute that they escape the sight; and that in disease the blood and humors are so intercepted that, being swollen, they then plainly strike the eye. If, however, such glands come to view in a diseased state I would hold them as a disease rather than as natural glands. Later, I came across parts of the choroid plexus which resembled glands; but examining them more accurately, I discovered them to be hydatids, being nothing else than vessels turgid with serum; for I do not hold with those who suppose that only lymphatics are turned to hydatids, since the extremities of blood vessels are especially subject to this ill. Daily inspection of corpses has made me quite certain of this." Ruysch cites the case of a man died of dropsy. On opening the body he found the whole liver, which is made up mostly of blood vessels, consisted of hydatids; on opening which, there flowed out a tenacious vitreous and transparent lymph. He cites also a case of an insane man in whom the choroid plexus was found to be full of hydatids. He adds, "This explains Vieusssens' statement that in a man of advanced age the choroid plexus seems to be made up not of blood vessels but rather of lymphatics. (*Epist.* xii, pp. 20-3.)*

[57.] It is worthy of consideration that the arteries of each of the convolutions of the cerebrum inosculate and unite with the arteries of the neighboring convolutitons. It must further be noted with respect to the convolutions of the cerebrum while still furnished with pia mater, that they never, seem to be so deep as when the pia mater has been taken away; their furrows and windings are then seen to be deeper. I will not say anything of Bidloo's imaginary and chimerical delineation of the glands of the cortical substance of the cerebrum, in which he represents that no blood vessels can be seen to pass through them either with the microscope or with the naked eye. (*Epist.* ix, pp. 9-10.) [*Fib.* 172.]

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*There is no indication in the FIBRE that our author cited this passage from Ruysch. We have added it, however, as an interesting contribution to the statement made in n. 130; see also 468, 560.

See Ruysch's plates where he shows the little threads that, after his particular mode of maceration, are drawn out as continued from the arteries; the membranous connection being loosened and the order disturbed, the immense quantity of vessels becomes apparent. (See Tab. xiv, xv; *Epist.* xii.) See also Tab. viii (*Epist.* vii) where he shows that the pia mater penetrates into the cerebrum in a serpentine manner and into the cerebellum in a falciform manner. Fig. 1 shows the pia mater of a cerebellum with its falciform processes, one of the latter being shown separately in Fig. 2. "The arterial vessels through this membrane are so numerous (says Ruysch) that had I shown them all I would have entirely obliterated the falciform processes." However, he shows a few of these vessels on the margin of his Figure, where it is seen that the inner surface of the pia mater exhibits a mossy covering of vessels which insinuate themselves into the cerebellum. Fig. 4 shows a porton of pia mater from the cerebrum with its processes insinuated between the convolutions. These are not falciform as in the cerebellum, but they creep along in a serpentine course. Fig. 3 shows one of these processes loosened from its fibrous and vascular connections and stretched out flat so as to show the winding course of the vessels. In this figure the cortical substance has been removed, and it consequently shows the empty compartments and cells formed by the winding arterioles according to the windings of the convolutions, and presenting the appearance as of a honeycomb.

See also the appearance of the little places or beds of the cortical substance within the serpentine processes of the pia mater next to the surface of the cerebrum in plate x; also plate xiv and plate xv, Fig. 7, which shows a medullary portion of the cerebrum from which all the cortical substance has been removed, leaving hollows or pittings of various depths. (*Epist.* ix, xii.) [*Fib.* 59.]

THE FIBRE

I.

THE CORTICAL AND CINERITIOUS SUBSTANCE.

57a. *The cerebrum, cerebellum, medulla oblongata and medulla spinalis consist mainly of two substances,—a Cortical or Cineritious, and a Medullary or White. The cortical or cineritious-colored substance lies just under the pia meninx, encompassing the cerebrum like a bark and densely encrusting it. It is also found within the cerebrum,—for example, behind the ventricles and in the posterior lobes,—where it is sparsely inserted in the white or medullary substance. This same substance also occupies the exterior parts of the cerebellum, though it there resides more sparsely; and it penetrates deeply into the cerebellum under the appearance of a branching tree. On the other hand, in the medulla oblongata,—for example, in its two principal and other eminences, as well as in the stem itself,—the cortical substance is interposed in the white substance in striæ or streaks; and in its downward course towards the great foramen of the occiput it is compressed and concentrated until at last it becomes an axis holding the interior position while the medullary portion is on the outside. In this way it flows down through the whole course of the spine up to the first lumbar processes where at last it is no longer continued.*

Hence in its descent, the cortical substance contracts from the peripheries to a central axis, and in its ascent, it spreads out from continual centres towards the peripheries. And this, in order that active forces and their endeavors to action may be concentrated before they are determined into act in the body; and that passive forces or sensations may be poured forth towards the peripheries before they are perceived in the common sensory which is the very circuit of the cortical cerebrum; thus in exactly the same way as in the great system or macrocosm.

Wherefore the cerebrum and cerebellum are found to be each divided into its hemispheres, and these again into their little hemispheres; and in the single divisions poles are formed and axes shadowed forth, to which the mediate substances constantly refer themselves by spiral circumvolutions. Such an architype of the universe is delineated in the brain, especially in the human brain, and most perfectly in its several parts.

And in order that the cortical spherules, which are so many forms of the forces of the little animal world and nature, may remain efficient, sufficient, and multiplied according to need, and that they may also be capable of expansion and compression both singly and conjointly, they are allotted a position in the spacious surface of both the brains,—a surface divided into tortuous windings, furrows and ridges,—just under the pia meninx and proximate to little arteries flowing with the better blood.

From these considerations it is quite apparent that in perfect and healthy brains and medullas, all things with their component parts are so disposed and ordered that nothing more disposed and more ordered can be conceived of in the whole of nature. For each single cortical spherule is so situate, and each fibre so flows, that it seems to itself to be in the centre, in the radius, in every point of the periphery and in a thousand points at the same time; and thus to be established in the very conatus of the single parts and in the motion of the whole; and hence in such state that, of itself and its own nature, it knows what the soul is intending in the beginnings and what she is doing in the extremes. Hence arises the order, ratio, unanimity, harmony and love which perpetually reigns between the single parts and the larger and smaller wholes in this microcosm.

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58. *The cerebrum, cerebellum, medulla oblongata and medulla spinalis consist mainly of two substances,—a Cortical or Cineritious, and a Medullary or White.* Malpighi, Ridley, Bartholin and other illustrious anatomists all agree that Piccolomineus was the first to observe the difference between these two substances, calling the cineritious body, which appears cloudy, somewhat turbidly transparent, and of a leaden or mouse color, and which first meets the eye, the Cerebrum proper, and the interior shining and white body, its Medulla or Marrow. Leeuwenhoek, on the other hand, examining the cortical substance to its very parts, found it to consist of extremely pellucid, crystalline and oily matter, and therefore he preferred to call it Vitreous rather than cortical. Perhaps also, by reason of the form and essence of its parts it might fitly be called Granular, Glandular, or Discrete, and the medullary substance, Fibrillar, Vascular, and Continuous. But the objection arises that the eye, the index of the mind, prefers differences marked by colors to those which are sought from the texture and form resulting from nature, because the latter flee the unaided sight. Nor should we rashly depart from received usages of speech when the thing expressed is equally well understood by the ancients as by ourselves. One thing should be carefully borne in mind, namely, that this substance is called Cortical when it constitutes the cortex (bark) or outer circuit of the brain, and Cineritious when it is sprinkled in the interior medullary substance.

But whence arises the diversity of color? The cortical or cineritious substance, which in itself is translucent, is thickly interspersed and beset with vessels of a reddish tinge, and is differentiated by continual little interstices. These induce a certain tempering and shade on the light of the parts, and thus, with the vanishing of this light, there arises a bluish grey color, like the grey of fresh ashes, or like a color growing from white to livid. The medullary substance, on the other hand, is woven solely of little vessels and fibres, each by itself equally pellucid; but by various winding paths these fibrous and vascular shoots run into flexures, they decussate and mount over each other, and, by mutual divarications, they form spongy plexuses which are beset with globules of diverse form, dimension, and nature, and with interjected fluids. Hence arises the whiteness. It is somewhat similar to the case of an aqueous or oily fluid, the white of an egg and other similar matters made up of purely diaphanous principles, when reduced into fibrous forms by means of a lixivial salt, or into bullular forms, that is, into froth, by shaking. Such also is the case with the diamond, crystal, glass, ice and other pellucid bodies; when such bodies are broken up into minute polygons and little pieces of differing forms, or when they are cut into chips, then, in place of pellucidity, there arises a bright and snowy color suitable for the reception of all other colors.

59. *The cortical or cineritious-colored substance lies just under the pia meninx, encompassing the cerebrum like a bark, and densely encrusting it.* So great is the luxuriance of the parts constituting this crust that they must be numbered by myriads of myriads, especially in the large human brain. Their marvellous number may be inferred from the density of the crust compared with the minuteness of the parts. But in Transaction II, in the chapters in the Motion of the Brain, and on the Cortex,* you will find it deduced from the experience of leading anatomists that there are as many forces of every animal kingdom, as many little brains, eyes, and internal sensories, and, moreover, as many leaping and animating points or little hearts, in a word, as many active principles and origins of motions and vital modes,—as there are substances of this cortex or cineritious body. I therefore leave to the reader to judge how great is their abundance, and how ordered their disposition. For they are co-ordinated in such a way that each single substance resides and acts freely in its own little space; a number of them then consociate together into a little ball or glome which is held distinct from its neighbor by its own fissures and little spaces; these glomes in their turn combine to form a more general glome, also bounded by clefts; and these more general glomes, again, unite together, weaving themselves into tracts, not unlike the convolutions of the intestines, and discriminated by winding interstices and comparatively wide furrows. Thus the cerebrum, which is born in this substance and primarily has its existence therein, grows by degrees from points to its own dimensions, and from parts in the most distinct manner into a body. The little places

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*The reference is to Economy of the Animal Kingdom, vol. II., no. 1 *seq.*, and 69 *seq.*

and beds occupied by this cortical substance lying between the serpentine processes [of the pia mater] next to the surface of the cerebrum, are shown by Ruysch in a single plate; see Transaction II, nos. 87, 147.

60. *It is also found within the cerebrum,—for example, behind the ventricles and in the postreme lobes,—where it is sparsely inserted in the white or medullary substance.* For if the cerebrum be cut along the hollow of the lateral or superior ventricles up to its extreme borders extended over the cerebellum, a dense medullary substance is exposed variegated with darkish streaks. Thus we again find the cineritious part mingled with the white, almost as pictured in Vieussens' figures. That the cineritious substance found in the recesses of the cerebrum, in the cerebellum, and in the medulla oblongata and medulla spinalis is of a similar stock and nature as that found in the circuit of the cerebrum, where it is called cortical, is made clear by the microscope, by the forms of the substances and their origins and offices, by the fibres springing from them, and by all other criteria. Malpighi therefore has no hesitation in asserting this fact, his words being, "The substance of the cortex observed in the ventricles of the cerebrum, and again at the beginning of the medulla spinalis, is of the same character [as that observed in the exterior region of the cerebrum]. . . . In the interior portion of almost the whole of the medulla spinalis the cortex, which I have described, retains the same glandular character." [*sup.* n. 19.] (Trans. II, n. 76.) And therefore from a distinct knowledge of the ordination of this substance we may conclude concerning the offices which each one of its congeries, wherever set, is to perform in the body. But this is a work, and requires labor (*Sed hoc opus, hic labor*).

61. *This same substance also occupies the exterior parts of the cerebellum, though it there resides more sparsely; and it penetrates deeply into the cerebellum under the appearance of a branching tree.* If the cerebellum be cut transversely up to the vermicular processes,* the great valve of the cerebrum† and the underlying ventricle or calamus scriptorius, and through the middle peduncle, the entire face of this tree will be exhibited to view; namely, a medullary trunk formed by the juncture of three stems, with its branches, twigs and leaves. For so does the pia mater wind its way; the capillary vessels press upon this membrane; from these vessels spring the cortical spherules; and on these grow the fibres, each being so disposed that, by discriminations of colors, light and shade, a spreading forest is represented. The cortex itself is born into this form as soon as it is brought forth, and into this form it begins to bud out from its tender infancy; for it straightway branches around its arterial mother, on whom it hangs like a cluster of grapes on its stem. Thus it is initiated into this its form from its first origin. Similar arboreal forms, effected by these two differently colored substances, are seen in the cerebrum, as is evident when any of the tori or glomes of its substance are cut transversely; cf. Trans. II, nos. 76, 79, 150. Thus the brain is seen to be a conglomeration of as many little brains as there are congeries of the cortical parts. The cause of this vegetation is evident, for in this way and no other can the cortical origins bring forth their offspring or fibres, and, having brought them forth, can nourish them in particular and in general, and educate and rule them; and they, depending on their arterial parent, can freely accomplish in the meningeal folds their modes and motions, can draw their breath, and be expanded and constricted.

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*The vermiform processes. †The valve of Vieussens.

62. *On the other hand, in the medulla oblongata,— for example, in its two principal and other eminences, as well as in the stem itself,—the cortical substance is interposed in the white substance in striæ or streaks.* As in the corpora striata, the thalami of the optic nerves,—called also the crura of the medulla oblongata—the annular protuberance,* the pyramidal and olivary bodies, and the stem of the medulla oblongata around the fourth ventricle. The bodies first mentioned are far more striated than the others, the optic thalami being subtly besprinkled with cineritious substance, or with tender little eyes. But at the extremity of the medulla oblongata, anterior to the great foramen of the cranium, the discriminations or striæ begin to run together; for the cineritious layers there converge into an axis. Thus we have the explanation of our next induction, namely, *And in its downward course toward the great foramen of the occiput it is compressed and concentrated until at last it becomes an axis holding the interior position while the medullary portion is on the outside.*

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*Pons Varolii.

63. *In this way it flows down through the whole course of the spine up to the first lumbar processes where, at last, it is no longer continued.* The first region of the spinal axis is called the cervical region, the second the dorsal, and the third the lumbar. The cineritious axis runs through the middle of this spinal cylinder or pipe, while the white substance occupies the surface,—just the opposite to what obtains in the cerebra. Then comes a medullary substance, emulous of the nerve, without any interspersed cineritious substance. This, descending like a cone, ends in an apex where it is called the cauda equina.

64. *Hence in its descent, the cortical substance contracts from the peripheries to a central axis, and in its ascent, it spreads out from continual centres towards the peripheries.* An axis is an elongated and continued centre; for in a cylinder, cone and other like figures there are as many centres as there are peripheries. The simple or circular figure enjoys only one centre; the ellipse, on the other hand, has many, extending from focus to focus; and so with other figures, respectively to their surfaces. But I would perhaps seem to be relating wonders, if I should say that there is a figure whose centre is in every point of the periphery, or whose periphery is made up of mere centres. Of this figure we shall treat in the following pages.

65. *And this, in order that active forces and their endeavors to action, may be concentrated before they are determined into act in the body.* It is well known even to tyros that the beginnings of all bodily actions are in the brains; for will and determination precedes the action itself which is effected by the motion of muscles. It is likewise also evident that the fibre drawn forth from the cortex of the cerebrum flows down through the medulla oblongata and medulla spinalis towards the origins of the nerves, and through these, it flows with the active forces of the cerebrum into the muscles. From these facts it now follows that the verimost beginnings of actions reside in the cortical substance of the cerebrum. These substances, therefore, may be deservedly called the forms of the forces of animal nature. But instead of active forces let us substitute the nature of heavy bodies, for the two mutually correspond. The light of experience shows that, for the sake of coming to a state of rest or equilibrium, heavy bodies are in a perpetual endeavor towards the centre of their sphere, called the centre of gravity, or to their *punctum immobile.* So it is also necessary that active forces, with which heavy bodies are compared, be concentrated in the brains, as in atmospheres, before they are determined into act, or give forth an effect. Aristotle seems also to have observed this, where he says, "The heavy is that which is prone to be borne to the middle, that is, to the centre; the most heavy, that which is gathered under all other bodies [which are borne downwards]. Everything that is borne upwards or downwards has either lightness or gravity, etc. A body which is borne in a circle cannot possibly have either gravity or lightness. Local motion in a straight line is not in accordance with nature herself." (*De Coelo.* lib. I. cap. iii.) He proves that neither what is borne to the middle nor what is borne from the middle can be infinite, because the middle is something definite. (*Ibid,* cap. vi.)

66. *And that passive forces or sensations may be poured forth towards the peripheries before they are perceived in the common sensory which is the very circuit of the cortical cerebrum.* Sensations, because they are modifications arising from touch and are received by the common sensory, are so many passions* of the soul, and, therefore, they are to be classed as light bodies which strive from centres to surfaces. For the sense of touch is carried by its own fibres into the axis of the medulla spinalis and thence upwards towards the cortex of the cerebrum; taste and hearing into the medulla oblongata, and thence by continuous fibres towards the same circuit; smell through the cribriform plate into the corpora striata above, and thence into the whole cineritious and cortical substance of the cerebrum; sight, like the rays of light or the modes of sound, runs by a still shorter route, namely, through the optic nerves, the thalami of those nerves, the striated medullary substance, and especially through the base of the fornix and the corpus callosum, into all the cortical spherules, which are so many little sensories, and internal eyes of the utmost acuteness. See Trans. II, nos. 191 to 195. *Thus in exactly the same way as in the great system or macrocosm.*

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*Passion is here used in its root meaning as opposed to action.

67. *Wherefore the cerebrum and cerebellum are found to be each divided into its hemispheres, and these again into their little hemispheres.* The cerebrum is divided by the falx and the longitudinal sinus; the cerebellum by the insinuation of the dura mater—though here the division is not so plain; and the medulla spinalis by the anterior fissure. In like manner also the cortical volumes of the cerebrum, and the lamellar insinuations of the cerebellum are divided by the falciform processes of the pia mater, and by little arterial quasi sinuses. So also the particular glomes of this same cortical substance, which represent a little brain in smaller type; see above, nos. 59, 61. Thus the brains are divided into their hemispheres and little hemispheres.

68. *And in the single divisions poles are formed, and axes shadowed forth.* As regards the *poles:* In the cerebellum near the vermicular processes they are delineated quite plainly by Eustachius and other anatomists. But in the cerebrum they are not seen so clearly; yet they are found in its prow, or in that part which lies just under the coronal spine* and the crest of the ethmoid bone. In some calf brains I have observed them quite plainly. To these cerebral poles all the gyres and convolutions of the cortical substances refer themselves, and also the winding paths and interposed insertions of the pia meninx.

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*The frontal crest.

Moreover, the larger interstices of the medullary substance converge towards the cribriform plate or the coronal spine mentioned above, from which point run the first sinus of the dura mater and the process of the falx.

With regard to the *axes,*—I speak of the common axis of the whole encephalon: It is a certain perpetual duct or channel, commencing almost from the fissure between the prominences of the cerebrum, and continued under the base of the fornix, through the third ventricle, the aqueduct of Sylvius and the calamus scriptorius up to the medulla of the spine, where it projects itself from the centre towards the surface. This channel runs through that region of the cerebrum which is most at rest. The single congeries of the cortical substance in the cerebrum have also their axes, if not visibly represented, still shadowed forth when we regard the form and determination of their motion. For it is a constant truth that a circumgyration, whirl, and motion, such as is that of the cerebrum, could never be effected without poles and axes, or without a respect to poles and axes; and unless these be investigated we ask in vain what the cerebrum does, and what its members and parts. Therefore I have bent all my powers to their investigation.

69. ***To which the mediate substances constantly refer themselves by spiral circumvolutions.*** It is a canon of geometry that where there are poles and axes there is also a spiral fluxion; and where there is a spiral fluxion there are poles, axes and larger and smaller circles, just as in the great sphere. Indeed it is evident from mere sight that the circumvolutions of the surface of the cerebrum wind into the curves and modes of a spire. But it is best to adduce the description given by Willis: "Within its single partitions, (he says), the whole structure of the cerebrum is seen to be still more divided and variegated. For its whole exterior surface is everywhere rendered uneven and tortuous by gyres and convolutions almost like those of the intestines. These gyres, proceeding by a sinuous winding, and, as it were, a spiral circuit, from the anterior part of the cerebrum to its posterior, surround both its hemispheres, one circumvolution succeeding another in a continued duct; that is, in such a way that at the bottom of any given furrow a convolution rising on the right side is carried to the left; then, immediately following it, another convolution is set up, emitted from the left side to the right; and in this order the inequalities of the whole cerebrum are alternately variegated." (*De Cerebro,* cap. x, sec. 3.)

70. If the whole mass of the cerebrum, and also its single congeries, flow into such a form of motion, what then must be thought concerning its least part or the cortical spherule? Do you not believe that here also are represented poles, axes and circles? Through the middle of such spherule runs a channel, which, like its common axis, is continued into the appended fibre. See Trans. II, nos. 124, 125, 126, 127. For in least things nature is pure and in the greatest freedom, and there she reigns with the utmost perfection in all her science, art, right, power, law, and court of action; nor can the common form, or the form of the entire cerebrum, result without the harmonious conflux of forms of a more perfect nature. Hence now follows our next induction which is already explained, namely, that *Such an architype of the universe is delineated in the brain, especially in the human brain, and most perfectly in its several parts.*

71. *And in order that the cortical spherules, which are so many forms of the forces of the little animal world and nature, may remain efficient, sufficient, and multiplied according to need, and that they may also be capable of expansion and compression both singly and conjointly, they are allotted a position in the spacious surface of both the brains,—a surface divided into tortuous windings, furrows and ridges,—just under the pia meninx and proximate to little arteries flowing with the better blood.* That the cortical spherules are so many forms of the forces of active nature, see the whole chapter on the Cortex, in Transaction II, [nos. 69-207]. That they are immensely multiplied, see above, n. 59, and Transaction II, nos. 140, 176-183. That they are capable of expansion both singly and conjointly, see Transaction II, nos. 153-159. That the surface is divided into tortuous windings, see above, n. 69. I pass by any exposition of the remaining parts of this induction, because they are clear.

72. *From these considerations it is quite apparent that in perfect and healthy brains and medullas all things, with their component parts, are so disposed and ordered that nothing more disposed and more ordered can be conceived of in the whole of nature.* See Trans. I, n. 248, *seq.* But, O how dull of perception are they who believe there is nothing regular, ordered and distinct, except what is acknowledged by the judgment of the eye! In the eyes of their mind is set, as it were, a cataract, and the points of rational light straightway turn them dizzy. If only they evolve visible phenomena to their causes, they will surely find nothing unarranged, nothing wandering in the chance of conflux, and without law.

73. *For each single cortical spherule is so situate, and each fibre so flows, that it seems to itself to be in the centre, in the radius, in every point of the periphery, and in a thousand points at the same time; and thus to be established in the very conatus of the single parts and in the motion of the whole; and hence in such state that, of itself and its own nature, it knows what the soul is intending in the beginnings, and what she is doing in the extremes.* Similar to what we find in the parts of the cerebrum, we find also in the parts of the atmosphere, as is abundantly evident from rays in the ether, sounds in the air and waves in the water. (Trans. I, n. 66.) It is most important to note that there is no least fibre or vessel which is not set in the very stream of the motion of the cerebrum, cerebellum, medulla oblongata and medulla spinalis, yea in the stream of the motion of every single viscus of the body. It is so with the carotid arteries situate between the lobes; with the branches of these arteries in the winding interstices; with the twigs of the branches between the ridges and around the glomes of cortical substances. It is so with the greatest vessels, as the longitudinal sinus between the hemispheres, and with the least, as the fibres in both meninges and in the medulla itself. When, under this rule, I examined the cerebrum and cerebellum with their viscera and appendices, I saw that it would be possible for me to trace out with some clearness the offices of them all,—a discovery which afforded me no little light and gladness.

74. *Hence arises the order, ratio, unanimity, harmony and love which perpetually reigns between the single parts and the larger and smaller wholes in this microcosm.* That everything is first founded in a centre, and contains within itself the reason for all that follows, and refers itself to all that precedes whereon it depends and by virtue whereof it exists as it does and in no other way, see Transaction II, nos. 252, 260. But you will find these things explained in our Psychological Transactions.*

II.

THE DETERMINATION OF THE MEDULLARY SUBSTANCE IN THE CEREBRUM

74a. *The medullary and white substance of the cerebrum is seen to exist and find its origin in the confines and termini of its cortical substance. Hence the medulla is a congeries of mutually interwoven fibres and little vessels which connect with each other in various ways, though for the most part after the manner of a network, and thus at intervals; and it comes forth as a globe almost egg-shaped, or as a great medullary nucleus, called by the old anatomists the Corpus Callosum, and by the modern, the Centrum Ovale. This globe is not a continuous globe, but is wonderfully cut up into members and cavities, such as eminences, tubercles, fornices, glands, ventricles, aqueducts, fissures; which, when deeply examined and weighed in the order in which they succeed each other and co-operate, indicate with some clearness that the cerebrum is a large gland, and a laboratory completely furnished with chemical organs, or vessels. For here we meet with pipes, bladders,*

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*In a manuscript outline of the "Transactions" which were to constitute the Economy of the Animal Kingdom, Swedenborg gives "Introduction to Rational Psychology" and "Rational Psychology" as the titles of Transactions V and VI respectively. It is presumably to these two Transactions that he refers when he says, "You will see these things explained *in psychologicis.*" The two latter words have therefore been rendered, "In our Psychological Transactions."

encased retorts, retorts that are serpentine, cups, filters, baths, and even vessels for cooling. For the vital juice, or animal spirit, is conceived and brought forth in the cortical substance, which are so many most perfect chemical laboratories, or most simple of nature's glands. Following the medullary threads through the corpus callosum, and thence across the base of the fornix and along its pillars and roots, it is exuded into the anterior ventricles near the choroid plexuses; and, commingled with the lymph destilled in these plexuses, and by the ministration of glandular tubercles, it is led down through two foramina into the third ventricle; and so, through the infundibulum and the filter of its beak into the pituitary gland, and from this by the little sinuses and receptacles of the sella Turcica into the jugular veins. To the end that the blood, returning from the brain dry and languid, and soon to be ingenerated with new chyle, and to go down into the right chamber of the heart, may be vivified with spirit. Hence also is derived the life of the blood whence is the life of the whole body. This, therefore, is the reason why the medullary globe of the cerebrum is distributed into so many members; of which the use of each will clearly reveal itself if we contemplate this machine as set in motion. For the whole mass, gaping with so many cavities and clefts, can readily rise up into a swelling, and alternately subside; or, it can be variously expanded and constricted. To this aforementioned laboratory and its chemical equipment, the fibre is drawn forth from the whole cortical circuit of the cerebrum.

Another kind of fibre of the same cerebrum, associated with the fibres of the corpora striata and the crura of the medulla oblongata, is sent out to the olfactory, the optic, and the other sensory nerves, building up these nerves together with their organs. All the remaining fibre is sent down from the anterior part of the cerebrum to the annular protuberance, and from its posterior part near the fourth ventricle to the medulla oblongata and beyond to the medulla spinalis; and is mingled with the fibres there originating, and also with fibres of the cerebellum, in order that it may also excite voluntary actions in the body.

From these considerations it is apparent that the fibre of *which the medullary body of the cerebrum is fabricated is principally devoted to three offices, namely, that it may conduct spirit and life to the blood; that it may transfer external sensations to the common sensory; and, lastly, that it may excite voluntary acts. But to trace out the origin whence the fibres of one function or the other spring, and, when this is found, the direction whither they tend,—this can never be detected without the guidance of ocular experience and of the experience of physical phenomena, combined with the conclusions of a rational and truly philosophic mind; nor can it be done synthetically before it has been done analytically.*

75. I have here undertaken to treat of the determinations of the fibre in the Cerebrum, the Cerebellum and both medullas,—the medulla of the head and that of the spine; that is to say, of the brains themselves and of their members or organs. But I shall treat of them only in a limited way, for they will be explained more fully in the Transactions that are to follow.* For it is one thing to treat of the fibre, but another to treat of the determination of the fibre. The latter subject involves every structure and organism; indeed it involves the universal anatomy both of the brain and of the body. For there is not a thing in the anatomical system that is not fabricated of fibre, or of a stem sent out from the brains.

76. *The medullary and white substance of the cerebrum is seen to exist and find its origin in the confines and termini of its cortical substance.* For there are vascular shoots or arterial terminations, drawn from the meningeal surface of the cerebrum, which insinuate themselves around and through its cortical substance into its medullary globe and centre. These shoots, because they are emulous of the genuine fibre, are said *to exist in the confines* of the cortical substance. But there are also genuine fibres, namely, such as arise from the spherules of the cortical substance, as from so many little brains and hearts and as from their own proper matrices. These, therefore, are said *to find their origin in the termini* of the cortical substance.

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*The Transactions referred to are evidently the treatises on "The Cerebrum" and "The Cerebellum," which were to have been Transactions III and IV respectively. They were translated by Dr. R. L. Tafel, and published as "The Brain" (two vols.).

77. *Hence the medulla is a congeries of mutually interwoven fibres, and little vessels which connect with each other in various ways, though for the most part after the manner of a network, and thus at intervals.* Nor must we omit to mention that genuine fibres, rising from their parent cortex, often retain among themselves a division not unlike that which obtains in the cortical conglomerations themselves; namely, that in one place they run out in bundles, in another in layers, and in still another like foliage, as is especially apparent in dropsical and hydrocephalic brains, where, by reason of the interjected lymph, the single divisions and connections come into view.

78. *And it comes forth as a globe almost egg-shaped, or as a great medullary nucleus, called by the old anatomists the Corpus Callosum, and by the modern the Centrum Ovale.* For with the removal of the cineritious crust which girds its trunk or nucleus like a rind, bark or shell, a purely medullary mass comes into view, similar in figure to the whole cerebrum. That this figure represents a great egg can be seen with the naked eye. But it is an egg almost cut into a half; for the superior part, which is also called the posterior, is quite convex, while the inferior or anterior part is somewhat plane. Moreover, by the insinuation of the process of the falx, this medullary nucleus is cut into above, and is thus divided into two hemispheres.

79. *This globe is not a continuous globe, but is wonderfully cut up into members and cavities, such as eminences, tubercles, fornices, glands, ventricles, aqueducts, fissures.* Each of these has its own distinctive name; for they are called: the corpus callosum; the fornix with its base, pillars, fimbriæ and roots; the septum lucidum; the anterior, lateral or large ventricles: the third or middle ventricle; the foramina vulva and anus;* the tubercles which guard the entrance, such as the pineal gland, the testes and the nates; the isthmus, which is the plane in which these tubercles are set. In the large ventricles are the corpora striata, and the crura of the medulla oblongata, or thalami of the optic nerves; through these ventricles runs the choroid plexus. From the third or middle ventricle is extended the beaked infundibulum, which is terminated in the pituitary gland. Not to mention the receptacula cavernosa,* the sinus of the sella Turcica† and of the base [of the brain],‡ the rete mirabile** and other parts, all of which will be treated of individually.

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*See note to n. 83.

80. *Which, when deeply examined and weighed in the order in which they succeed each other and co-operate, indicate with some clearness that the cerebrum is a large gland, and a laboratory completely furnished with chemical organs or vessels.* This is according to the opinion of Hippocrates and the ancients, and also of Malpighi and many other more recent authors, all of whom assert that the cerebrum is a gland, and this not only in particular, but also as a whole. That it is indeed a gland will be seen in the Transactions on the cerebrum. In the meantime, when it is called a gland, a natural chemical laboratory is meant; for in the glands, animal nature, by secretion, excretion, commixture and cohobation, prepares her menstrua and juices,—as saliva, chyle, milk, bile, the genital fluid—with such science and so wondrously that art may regard its nature as everything, and itself as relatively nothing. The cerebrum is the very exemplar of all the glands of the body, than to search into which, nothing more delightful is offered. *For here we meet with pipes, bladders, encased retorts, retorts that are serpentine, cups, filters, baths, and even vessels for cooling.*

81. *For the vital juice or animal spirit is conceived and*

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*The cavernous sinuses.

†The circular sinus.

‡The transverse sinus.

**Swedenborg defines the *rete mirabile* as the "reticular plexus in the duplicature of the dura mater at the sides of the sella near the circular sinus, threads of which are despatched into the pituitary gland" (The Brain, II, p. 201).

brought forth in the cortical substances, which are so many most perfect chemical laboratories, or most simple of nature's glands. That such is the nature of this substance, is, I think, shown in Transaction II, in the chapter On the Cortical Substance of the Brain; cf. nos. 110-132 and 165-176. That the animal spirit is the vital juice itself, see in a Transaction dealing with this spirit.*

82. *Following the medullary threads through the corpus callosum.* Immediately subjacent to the falx is a certain serpentine span, and, as it were, extended dorsum, purely medullary in composition, into which fibres are drawn, inflow and run together from the whole cortical periphery. This span or dorsum is called by Willis and other anatomists the Corpus Callosum, but by Vieussens the true Fornix. By means of it as by a bridge thrown between the two hemispheres, the medulla of one hemisphere communicates with that of the other; or, it is the combined containant of the medullary soil of both hemispheres. Moreover it is the threshold leading to the penetralia of the cerebrum itself. The fibre, led hither from every point of the cerebrum, is again gathered into a certain peduncle called the base of the fornix; but the fibres compacted into this base or trunk are soon separated and unfolded over the thalami of the optic nerves in the lateral ventricles, like the roots or branches of a leafy tree, and are implanted in the thalami themselves near the choroid plexuses. Such is the passage of the fibres from the cortical circuit of the cerebrum, and such their unfolding; thus according to our description: *and thence across the base of the fornix and along its pillars and roots, it is exuded into the anterior ventricles near the choroid plexuses.*

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*Many of the subjects which were to have been included in the Transactions of the Economy of the Animal Kingdom, were dealt with by Swedenborg at various periods, with greater or less completeness, and with the intention of subsequently incorporating them among the Transactions. These works have been preserved in MSS., and most, if not all of them, have been published in the original Latin. Among them are the Rational Psychology, Ontology, Generation, etc., besides a number of smaller works, including one on the Animal Spirit. This latter seems to be a sketch of the Transaction referred to in the text. It may be found in English translation in the Posthumous Tracts.

83. *And, commingled with the lymph destilled in these plexuses, and by the ministration of glandular tubercles, it is led down through two foramina into the third ventricle.* Between the large cavities of the cerebrum, called the lateral ventricles, is a long but expansile cleft, or third ventricle, below which the lymph channel is continued to the great valve,* which is followed by the fourth ventricle and the calamus scriptorius carved in the stem of the medulla oblongata. This cleft or third ventricle, rising not far from the fissure between the bosses of the cerebrum, is continued as a hollow axis running through the middle of the septum lucidum, under the forked base of the fornix, and the corpus callosum, and between the crura in the medulla oblongata, to the beginning of the medulla spinalis, though it is intercepted by barriers. The foramina which lead into it from the lateral ventricles are called by the old anatomists the vulva and anus.† The glandular tubercles which minister, and guard, close, and open the way, are the pineal gland, the nates and the testes.*

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*The valve of Vieussens.

†The vulva and anus, called by Winslow the common anterior and posterior foramina, are two openings between the lateral and third ventricles. Both were well known to Swedenborg's contemporaries, and even to the ancients, but soon after Swedenborg's time the knowledge seems to have been generally lost. Haller, in 1762, denied that there was any communication between these ventricles; but in 1783 Monro conclusively demonstrated the existence of the anterior foramen or vulva, which has since been known as the foramen of Monro. This anatomist, however, denied the existence of any posterior communication between the lateral and third ventricles. But in 1872 the existence of this also was clearly demonstrated by the researches of Mierzejewsky, whose discovery, however, seems to be unknown, or at any rate unnoticed, by modern anatomists. Mierzejewsky's injections showed that there was a posterior foramen in the lateral ventricle in the neighborhood of the pineal gland. That this foramen is identical with the anus of the ancients is evident from the descriptions. Vieussens describes the anus as being under the base of the fornix near the anterior tubercle of the corpora quadrigemina. Ridley gives a similar description, placing the foramen under the pineal gland; and Winslow describes it as the interstice where the two anterior corpora quadrigemina join the convexity

84. *And so, through the infundibulum, and the filter of its beak into the pituitary gland, and from this by the little sinuses and receptacles of the sella Turcica into the jugular veins.* In the middle of the floor of the third ventricle is extended a coniform cavity, called the infundibulum, whose beak or apex is inserted into the pituitary gland. In the human brain this beaked extremity of the infundibulum appears to be impervious both to injections and to the lymphs; hence the opinion has arisen that the animal or most purely vital juice cannot pass through it. The pituitary gland is set in a little hollow in the centre of the sphenoid bone, and this in such a way that it can be freely expanded in its saddle in every direction. Into the middle of this gland girt with its bony wall, and around it, open the most subtle passages running from the infundibulum through its beak. And, again, there are apertures leading from the middle of the gland and from the space around it, into little sinuses, the receptacula cavernosa and the bones of the cranium, and, from these, into the lateral sinuses and the jugular veins which take up all the blood of both cerebra and carry it back to the heart. Such is the continuous connection of the members and cavities of the cerebrum; and that such also is the flow of the spirits cannot be doubted. In the Transactions on the Brain it will be shown that the spirit, which is most volatile, when it leaves its fibres, must be taken up, and, as it were, fixed in the ventricles by a lymph secreted from the choroid plexuses, lest it be evaporated. And then it must be filtered and purged by passage through the beak of the infundibulum, in order that the better essence may penetrate the pituitary gland, and the rest, flowing into the space by which that gland is circumscribed, may be derived by divers paths

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of the optic thalamus. See an interesting discussion of this whole question by Dr. R. L. Tafel in his translation of The Brain, Vol. I., pp., 751, *seq.*

*Called also the quadrigeminal bodies, the nates being the superior and the testes the inferior.

into the venous blood. "Does it then seem strange to you (says Boerhaave) that the eye does not take in the presence [and motion] of this humor? that ligatures, wounds, punctures, suctions, air-pumps, and injections are of no avail to exhibit it to the eye? that by no art can the cavities [of the nerves] be set before the keenness of its vision? He who attempts these things with this intention, truly knows nothing of the nature of these vessels and of the liquor itself. But he who, because they flee the sight and elude all skill, therefore denies the existence of cavities in these little vessels, is wholly ignorant of the rationale of our body in its origin, its progress, its operations, and its excretions; neither does he know the structure of insects, nor attend to all that so manifestly takes place in plants. This humor, by reason of its perfect simplicity, mobility [and volatility], we call the Spirit of the nerves,—a spirit which is natural, vital and animal." (*sup.* n. 51.)

85. *For the end that the blood, returning from the brain dry and languid.* It is known that the better blood is withdrawn towards the brains, or to the supreme court of the body and the presence-chamber of the soul, and is there devoted to its rational functions; yea that the spirit of the dissolved blood is again poured into the fibres; cf. Trans. II, nos. 117-132. That this spirit is the principal substance entering into the composition of the blood, see Trans. I, n. 37, 38, 40, 41, 91, 97, 100, 190, 271, 503, 556, 634. Hence it follows that in the brains the blood is despoiled of its spirituous nature and essence; and, therefore, its residual part comes forth comparatively dry and languid. That the fluidity of the blood results from its spirit, see Trans. I, n. 102, 556. Thus, unless it be refreshed with a supply of new spirit, it would become wholly torpid and unable to descend through the jugular veins. Hence would arise obstruction, the loss of sensations, of memory, and of voluntary and natural actions, the cessation of respiration and pulsation, in a word, inevitable death.

86. *And soon to be ingenerated with new chyle, and to go down into the right chamber of the heart, may be vivified* *with spirit.* As soon as the jugular vein containing the blood of the cerebrum is implanted in the subclavian, new chyle runs to meet it through the thoracic duct, and unless a better blood, or one impregnated with spirit, were at once poured in, the fluid would become sluggish, and, with elements crude and not of themselves fluent, would stop up, not only its own veins, but also the right auricle and ventricle of the heart. This danger, therefore, is avoided by the pouring in of spirituous blood. *Hence also is derived the life of the blood, whence is the life of the whole body. This, therefore, is the reason why the medullary globe of the cerebrum is distributed into so many members.*

87. *Of which the use of each will clearly reveal itself if we contemplate this machine as set in motion.* On the systole and diastole, or the animation, of the cerebrum, see Transaction II, chapters I and II, and especially n. 132-147; see also above, n. 68-74. It is almost the same as with the rationale of the pneumatic machine; unless you have seen this machine set in motion you will hesitate for a long time as to the use of the shafts, and screws, and their attached levers and ropes. So also is it with the brains.

88. *For the whole mass, gaping with so many cavities and clefts, can readily rise up into a swelling, and alternately subside; or, it can be variously expanded and constricted.* The cerebrum is a machine in motion and conformed and wholly adapted to motion, or to the faculty of expansion, both in general and in every particular. *In general;* for there is a space between the two meninges, the thick and the thin; there is a space between the convolutions called anfractuosities; there are little fossæ and furrows about every congeries of the cortical substances in particular; there are cavities deeply set in the medulla itself, namely, the three ventricles with the other continuous passages. Thus the cerebrum is given the faculty and the opportunity of swelling and unswelling both towards its exteriors and towards its interiors. *In every particular:* There are little spaces and clefts about every cortical spherule; the same are found between every least and compound fibre, for they are connected together after the manner of a network. This is the reason why each single part of the cerebrum is seen to be evidently set in the stream of the motion of all the parts; see above, n. 68 to 74. It is moreover necessary that the cerebrum be formed to this expansibility, for without actual motion or an active force in causes, nothing of the blood would ever be withdrawn from the kingdom of the heart, *i. e.,* from the body; nor would the spirits be poured through the fibres into the lower provinces; thus neither would the lungs breathe, nor the arteries and heart pulsate. If the fountain be still how much more the streams and brooks? If causes cease whence shall come effects?

89. *To this aforementioned laboratory and its chemical equipment the fibre is drawn forth from the whole cortical circuit of the cerebrum.* We have now treated of the determination of those fibres which are expended on the chemical members and operations of the cerebrum. The remaining fibres of which we now treat are not derived to the corpus callosum, and through the base of the fornix to the ventricles, but, at once associated with the fibres of the head of the medulla oblongata, they gird themselves for the performance of other uses.

90. *Another kind of fibre of the same cerebrum, associated with the fibres of the corpora striata and the crura of the medulla oblongata, is sent out to the olfactory, the optic and the other sensory nerves, building up these nerves together with their organs.* The olfactory nerves, or mamillary processes,* which are affixed to the anterior face of the cerebrum like two bottles, take their widely scattered roots from the region of the corpora striata. The optic nerves take their roots from the crura of the medulla oblongata, also called the thalami of the optic nerves; the auditory or seventh pair† from the annular protuberance, which is also the origin of the gustatory or fifth pair; the nerves of touch from all the nerves of the medulla spinalis. All these nerves raise up, in their extremities, organic forms corresponding to the degrees, measures and laws of the modes and forces flowing into them, or of contact [with these forces].

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*The olfactory bulbs.

†Now called the eighth pair.

91. *All the remaining fibre is sent down from the anterior part of the cerebrum to the annular protuberance, and from its posterior part near the fourth ventricle, to the medulla oblongata and beyond to the medulla spinalis; and is mingled with the fibres there originating, and also with fibres of the cerebellum, in order that it may also excite voluntary actions in the body.* The ocular experience of Vieussens, Willis and other anatomists tells us of the emigration of fibres from the cerebrum to the medulla oblongata and medulla spinalis and of their consociation with fibres of the cerebellum; and the physical and theoretical experience of phenomena confirms them. For voluntary acts wheresoever they are excited do not exist except with deliberation, and the assent and imprint of the cerebrum. For endeavors to action, or active forces, before they break out into ultimate act must descend from the peripheries like heavy bodies, according to the theory set forth above, n. 65. Therefore, the fibre of the cerebrum is never sent away singly except to its first functions or chemical operations. of which we have already treated; consult the words of Boerhaave quoted above, n. 46, 47. *From these considerations it is apparent that the fibre of which the medullary body of the cerebrum is fabricated, is principally devoted to three offices, namely, that it may conduct spirit and life to the blood; that it may transfer external sensations to the common sensory; and, lastly, that it may excite voluntary acts.*

92. *But to trace out the origin whence the fibres of one function or the other spring, and, when this is found, the direction whither they tend,—this can never be detected without the guidance of ocular experience and of the experience of physical phenomena, combined with the conclusions of a rational and truly philosophic mind.* For in the cerebrum all things appear soft like paste, coherent like a knotted mass inextricable alike to the stylus, the scalpel, and the eye, even when this is armed with the microscope. Moreover the fibrous structure, collected into intricate molecules and globules, and partly also into fascicles, runs together under the finger at the slightest touch, and therefore we must betake ourselves to experimental phenomena. For, to men of a penetrating genius, effects springing from the modifications of fibres or of organic forms in the extremes, and corresponding to the primes in their natal soil, indicate with some clearness the action and passion of the mediate fibres, and whence these fibres come and whither they go. But there is need of much investigation and rational intuition.

93. *Nor can it be done synthetically before it has been done analytically.* There are two ways and methods of opening and exploring nature,—the analytic, which consists in judging and concluding origins, causes, and principles from phenomena, effects and experience, that is, *ex posteriori;* and the synthetic, which consists in judging effects and phenomena from causes and principles, that is, *ex priori.* The former method is familiar to human minds because it is the natural method; for, as we grow up, we ascend to the sciences, and to our reasonings and judgments by the path of the senses whereby phenomena are received. But the latter method is proper only to pure souls and to spirits separated from the body,—a method to which we approach with maturing years so far as we recede from the body. Therefore he who, as though he were divinely inspired, starts immaturely and precociously to at once reason concerning the unseen things of nature from principles not explored by the analytic way or by experience, readily seizes upon empty shades, and fashions out spectres of whom nothing but the like is begotten. So long as we live in this lowly nature we must first ascend before we can descend; for as we were cast down from heaven where are the principles of things to the earth, so must we strive thither before we speak from principles. This, then, is the reason why, in our Transactions, I have labored to direct myself analytically from premised experimental proofs, or *ex posteriori,* to causes and principles, before I dared to descend synthetically, from principles, or *ex priori,* to effects. This is the true art and method of dialectics, or of drawing conclusions, for "He is a dialectician who looks into matters accurately and has penetration into the nature of the things concerning which judgment is to be made." (Plato, De Repub: lib. VIII, [?VII].)

III.

THE DETERMINATION OF THE MEDULLARY SUBSTANCE IN THE CEREBELLUM.

93a. *The medullary or white substance in the cerebellum is not conglomerated into an ovi-form nucleus, like that of the cerebrum, cut up into distinct members and cavities; but, from a somewhat ample space, it finally coalesces into a trunk, called a peduncle, made up mainly of three, as it were, arboreal stems or lesser trunks.. This peduncle into which all the fibres of the cerebellum are gathered together from the peripheries here and there, is planted on both sides of a cleft called the fourth ventricle and calamus scriptorius. From this ground it unfolds its fibres like roots, and sets them free in every direction, by three bundles, called processes. The first process goes to the opposite region, that is, to the annular protuberance; the second to the superior region where are the testes; and the third, called the restiform body, to the inferior region towards the medulla spinalis. All these fibres of the cerebellum, thus spread apart, meet and entwine themselves in the fibres of the cerebrum and in the fibres proper to the two medullas; and thus they gird themselves for performing their offices in the head and body, both distinctly and conjointly. This globe, although a continuous structure, is still given the unimpeded faculty of expansion both lengthwise and breadthwise, and also in general and in particular. For, besides the space between the meninges, its surface is also divided into deeply furrowed layers, or into little rings. Of these, the upper, stretched breadthwise, refer themselves to a certain corrugated axis, called the vermicular process, and from this to their poles; while the lower, drawn obliquely and lengthwise, refer themselves to a similar corrugated process in the inferior part of the cerebellum, situate transversely to the former.*

Meanwhile, the position and foldings of the vermicular processes, the insinuation and direction of the furrows, and, moreover, the actual existence of poles in the surface, all lead to an indubitable conclusion as to the nature of the mode of the *expansion and of the form of the motion; namely, that it twists itself after the manner of a perpetual circle, that is to say, spirally. On this account there are pivots, axes and poles, all of which necessarily suppose and thus indicate the existence of a spiral flux. Moreover, the peduncle towards which the forces of the whole mass are inwardly directed, is attached to an expansile cavity, carved in the stem of the medulla oblongata.*

From these considerations it can be seen that the cerebellum is one grand bed of cineritious and medullary substance, which by the forces of its animation pours a copious and continuous stream of spirits into all its nerves, and through these into the organs, glands and muscles,—and this constantly and in a single manner. Hence come forth natural actions and the stupendous operations of animal nature; for every single bud of this tree looks to its twig, the twig to its branch, and the branch to its trunk; so every particle of the cineritious substance looks to its fibre, and all together to the stem, made up of fibres, which the cerebellum, at every alternation of its expansion and constriction, leads to and fro in the yielding ventricle below.

94. *The medullary or white substance in the cerebellum is not conglomerated into an ovi-form nucleus, like that of the cerebrum, cut up into distinct members and cavities; but, from a somewhat ample space, it finally coalesces into a trunk, called a peduncle, made up mainly of three, as it were, arboreal stems or lesser trunks.* There is indeed a medullary space in the cerebellum, which, when cut across, presents a somewhat broad area, called by Vieussens the semicircular centre of the cerebellum; for here, as in other places, the newborn medullary substance first expands, and, as it were, relaxes before it comes together and is constricted. What should be noted is that there are three little trees which coalesce and unite together into one stem or peduncle, as is clearly seen from the figures of Heister* and other anatomists; there are also three processes, (spoken of below), which go out from the united stem and proceed to their ordained provinces. There is ground, therefore, for supposing that each process springs from its own particular tree.

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*Heister delineates a human cerebellum, and also the cerebellum of a calf, both cut into two halves by vertical section. In the calf, the medullary nucleus is clearly depicted as formed from

95. *This peduncle into which all the fibres of the cerebellum are gathered together from the peripheries, here and there, is planted on both sides of a cleft, called the fourth ventricle and calamus scriptorius.* It is fixed in the borders of this cavity, and this for a reason of which we shall speak below. In defunct and collapsed brains this cavity appears like a cleft, but in living and animate brains, when they are in the vigor of perpetual and alternate motions, it is seen to be both able and accustomed to expand into an oval gap and cavity. Its superior part, which lies next to the great valve of the cerebrum and closely subjacent to the vermicular process, is called the fourth ventricle, while the inferior part, verging towards the great foramen of the occiput, by reason of its figure, is called the calamus scriptorius.

96. *From this ground it unfolds its fibres like roots, and sets them free in every direction, by three bundles, called processes.* In the animal kingdom and also in the vegetable, yea, in universal created nature, it is nature's constant rule that singulars and particulars are reduced to some universal and common unit before they go off to their parts, *i. e.,* before they diffuse themselves; and this for the end that the scattered parts, each of which carries its own nature and its own bent, may perpetually refer themselves to the commonwealth, or the single members to the united city; thus, and in no other way, do the parts breathe in common, and unanimously look to one end. So also is it in the cerebrum, where the scattered fibres of the peripheries are gathered together, first, into the corpus callosum, and from this into the base of the fornix, that is, into a similar peduncle, before they are dismissed to their own colonies. The like also obtains in the nerves. For the present,

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the junction of three main stems. The same is true of the human cerebellum but here each of the three stems becomes divided in close proximity to the medullary nucleus. See Heister, *Comp: Anat:* tab. iv, fig. 16, 17.

the loose and scattered character of the medullary structure, in both the cerebrum and the cerebellum, may be sufficiently inferred from the fact that the entire globular mass, expanded into so great a space, suffers itself to be contracted into a narrow stem.

97. *The first process goes to the opposite region, that is, to the annular protuberance; the second to the superior region, where are the testes; and the third, called the restiform body, to the inferior region towards the medulla spinalis.* But the manner in which these radical fibres branch out cannot well be seen without some representation of them in plates or an inspection of the living brain. The reader, therefore, should consult [anatomical] treatises.

98. *All these fibres of the cerebellum, thus spread apart, meet and entwine themselves in the fibres of the cerebrum and in the fibres proper to the two medullas, and thus they gird themselves for performing their offices in the head and body both distinctly and conjointly.* It was pointed out above [n. 90, 91] that the fibres of the cerebrum associated with the fibres of the superior beginnings of the medulla oblongata pass out from the cerebrum anteriorly toward the annular protuberance, and superiorly to the neighborhood of the testes. Hither, also, come the fibres of the cerebellum, so that they seem predestined to be carried into the embrace of the approaching fibres of the cerebrum. In the annular protuberance, the fibres curve themselves into continual semicircles; but under the testes they form a girdle, whereby they constrict, as it were with a bond, that medullary tract which is the central portion of the whole encephalon. But whither they betake themselves after this, escapes even the keenest sight; we must suppose, however, that they go partly into the sensory and motor nerves of the head, and partly to like nerves in the medulla spinalis,—a supposition which is confirmed by experience. The same opinion is also entertained by Boerhaave, who says: "We may well believe that the medullary fibrils of the cerebellum—a body whose medulla gives forth no nerve—ascend upwards from a situation beneath the commissure toward the anterior parts of the medulla oblongata and there give to the nerves rising from the cerebral medulla, certain fibrils of the cerebellum, the distinction in origin, progress, and office being always accurately preserved. . . . The other fibres of the cerebellum are so mingled with the fibres of the cerebrum that there is perhaps hardly a part of the whole medulla oblongata and medulla spinalis, where fibres of the cerebrum are not found commingled with those of the cerebellum; so that, in the composition of the body of the nerve, they are certainly everywhere concurrent for the production of wholly diverse and distinct effects" (*sup. n.* 48).

99. *This globe, although a continuous structure, is still given the unimpeded faculty of expansion, both lengthwise and breadthwise, and also in general and in particular.* But by what wonderful nature and art, will be seen in what follows. *For, besides the space between the meninges, its surface is also divided into deeply furrowed layers, or into little rings. Of these the upper, stretched breadthwise, refer themselves to a certain corrugated axis, called the vermicular process, and from this to their poles; while the lower, drawn obliquely and lengthwise, refer themselves to a similar corrugated process in the inferior part of the cerebellum situate transversely to the former.* The superior part of the cerebellum, underlying the postreme lobes of the cerebrum, is comparatively depressed and flat, but when we come to the inferior and anterior part, it becomes more sharply rounded and the cerebellum there assumes almost the shape of a globe. When the surface of this portion of the cerebellum is exposed up to the first meninges, there comes to view an appearance and arrangement of little rings into which the surface is plowed. In the superior surface these separate ridges or furrows are somewhat removed from mutual contact, but in their progress forward to the sides and towards the base of the brain, they closely approach each other and there insert themselves in other fissures, which, after making some wonderful curves and contortions, terminate around certain slightly elevated protuberances, which induce on the furrowed surface, an appearance as of lobes. In these lobes, protuberances, or sub-divisions, there is a change in the direction and order of the ridges; indeed, this direction is frequently opposite to that which, in general, progress from the superior circuit of the organ to its margins. There are many subdivided surfaces of this kind on both sides around the medulla oblongata, whose margins they press. The superior rings are drawn towards a certain axis, twisted like a worm, which is called the vermicular appendix, and in which they all, as it were, knot themselves. So also on the other side where we see a similar appendix, but situate transversely to the former. There are also poles not far from the superior vermicular process. This process is noted and delineated by Eustachius [Table XVII], fig. vii.* Meanwhile, we note that the cerebellum is a globe so knotted and a structure so intricate, that it escapes the industry of the most skillful investigator. In one place the insinuated folds and duplicatures of the pia meninx are set free and spread out; in another they so infold themselves that the joinings disappear. The insinuation, ramification, attenuation and expansion of the meninx and blood vessels, as they betake themselves into the most secret recesses, is so ineffable that the whole organ, from its surface to its inmost parts, must be esteemed as a connected and continuous structure, and one so woven, as it were, of intricate threads, that it would be an inextricable knot, unless nature, while living therein, extricated herself, as she has infolded herself, according to the connections herself has formed.

100. *Meanwhile, the position and foldings of the vermicular processes, the insinuation and direction of the furrows and, moreover, the actual existence of poles in the surface, all lead to an indubitable conclusion as to the nature of the mode of the expansion and of the form of the motion; namely, that it twists itself after the manner of a perpetual circle, that is to say, spirally. On this account there are pivots, axes and poles, all of which necessarily suppose and thus indicate the existence of a spiral flux.* Such a spiral flux and torsion around a pole is shown in Eustachius's Table, referred to above. For the other points of this Induction, see the Transaction on the Cerebellum.

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*This is a delineation of the inferior surface of the cerebellum, after the removal of the Pons and Medulla.

101. *Moreover, the peduncle towards which the forces of the whole mass are inwardly directed, is attached to an expansile cavity, carved in the stem of the medulla oblongata.* For it is so implanted in both borders of this cavity that he who searches into the single particulars, and reflects upon them, cannot but see and acknowledge, unless he be mentally blind, that at every alternation in the animation of the cerebellum, this subjacent cleft opens and its lips are drawn apart, or, that it changes from a cleft to a ventricle or from a line to a figure. The peduncle of the cerebrum, or the base of the fornix, (of which above), is likewise girt about on every side by fissures and ventricles, whereby it receives a similar faculty for expansion and contraction.

102. *From these considerations it can be seen that the cerebellum is one grand bed of cineritious and medullary substance, which by the forces of its animation pours a copious and ever fresh stream of spirits into all its nerves and through these into the organs, glands and muscles,—and this constantly and in a single manner.* In this respect the cerebellum differs from the cerebrum, which latter consists of many conglomerated beds of this kind, that is to say, of many little cerebra. Whereever there is a fibre and an origin thereof, or a cortical substance, there streams the animal juice. For the fibres are so many little canals and the cortical substances so many laboratories and supereminent glandules which give birth to new spirit and transmit the old spirit, or that which returns from the arteries; see Transaction II, No. 165.

103. *Whence come forth natural actions and the stupendous operations of animal nature.* The common opinion still holds good, namely, that the cerebellum presides over natural, called also involuntary and spontaneous actions, and the cerebrum over voluntary, (Transaction II, n. 162). The reason of this is a consequence of the very disposition of the cortical substances, or active forces, that is, of the form which makes things to be such as we find them. (Transaction II, n. 244.) I think, therefore, that I have sufficiently set forth the nature of the ordering of the parts in the cerebrum and cerebellum, and of the form of the motion; and from this, the clear sighted philosopher can be in no obscurity as to the nature of the effect which will come forth. I desire now to state this form more distinctly, in the following words: *For every single bud of this tree looks to its twig, the twig to its branch, and the branch to its trunk; so every particle of the cineritious substance looks to its fibre, and all together to the stem, made up of fibres, which the cerebellum, at every alternation of its expansion and constriction, leads to and fro in the yielding ventricle below.*

IV.

ON THE DETERMINATION OF THE MEDULLARY SUBSTANCE IN THE MEDULLA OBLONGATA.

103a. *In the Medulla Oblongata, the medullary substance, made up of little arterial branches, of fibres from its own cineritious substance, and especially of fibres brought from the cerebrum and cerebellum, takes its origin in the corpora striata and the thalami of the optic nerves which are called the superior beginnings of the medulla oblongata. But it is soon dilated into a kind of ring-shaped protuberance and also into two other protuberances, called the pyramidal and olivary, situate below; from this point it is then contracted into a somewhat narrow stem at the great foramen of the occiput. On the posterior side, it is split into a long cleft, which constitutes the fourth ventricle. From this common appendix of both brains, the associated fibres, joined together into beginnings, into tender little fascicles, and finally into sensory and motor nerves, hasten forth through the foramina carved in the cranium, to the work of constructing the organic machine of the body. The protuberant bodies of this medulla expand and contract according to the direction of the fluent fibres, or according to their acquired form; and they do this both breadthwise and lengthwise, and also in unity with the brains, both in general and in particular.*

The spaces between the meninges, the lateral ventricles and also the fourth ventricle, the interior sanguineous receptacles, *the intercalated clefts and retiform plexuses, all give abundant opportunity for this expansion. But the specific directions are as many as are the beginnings of the nerves that issue forth, and to which as to peduncles the expansory motion is determined. But in general they tend towards the medulla spinalis; in order, however, that they may suitably refer themselves to this point, they finally curve around from the anterior portion of the medulla oblongata to its posterior, towards the fourth ventricle, and thus to the posterior portion of the medulla spinalis.*

104. *In the medulla oblongata, the medullary substance, made up of little arterial branches, of fibres from its own cineritious substance, and especially of fibres brought from the cerebrum and cerebellum, takes its origin in the corpora striata and the thalami of the optic nerves which are called the superior beginnings of the medulla oblongata.* There are some who suppose that these superior striate bodies* are to be reckoned among the members of the cerebrum because they constitute the floor of the lateral ventricles, and because the middle fissure or third ventricle, together with the infundibulum, is extended entirely between the crura or thalami,† that is to say, where their heads come together. But since it is not a matter of much importance to determine what parts are to be assigned to the cerebrum and what to the medulla oblongata, I merely mention the matter and leave it to the decision of the reader. For the medulla oblongata itself is, for the most part, a coagmentation of concurrent and coalescing fibres from the cerebrum and cerebellum, and in this respect it might well be called the appendix of both brains. But the striate bodies above, rise from their own origins or cortical substances, and in these are mingled fibres of the cerebrum only, but not of the

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**Corpora striata.* The term here includes both the corpora striata proper and the optic thalami. The latter were sometimes called the superior posterior corpora striata, for, like the corpora striata proper, they are *streaked* with white and gray matter.

†The optic thalami were sometimes called the crura of the medulla oblongata.

cerebellum; hence the part constituted by these bodies should properly be designated as the medulla oblongata of the cerebrum. For the fibres of the cerebellum do not meet the fibres of the cerebrum, except in the annular protuberance and just above the fourth ventricle, where this medulla begins to be the appendix of both organs.

105. *But it is soon dilated into a kind of ring-shaped protuberance* and also into two other protuberances, called the pyramidal and olivary, situate below; from this point it is then contracted into a somewhat narrow stem at the great foramen of the occiput. On the posterior side, it is split into a long cleft, which constitutes the fourth ventricle. From this common appendix of both brains, the associated fibres, joined together into beginnings, into tender little bundles, and finally into sensory and motor nerves, hasten forth, through the foramina carved in the cranium, to the work of constructing the organic machine of the body.* I pass by any further description of these matters, because they do not readily come to the apprehension of the understanding without some idea acquired from plates. The reader should, therefore, consult [anatomical] treatises.

106. *The protuberant bodies of this medulla expand and contract according to the direction of the fluent fibres, or according to their acquired form; and they do this both breadthwise and lengthwise, and also in unity with the brains, both in general and in particular.* We cannot indeed behold the motion of this organ, for it lies underneath the brains and is guarded and defended by the strong basilar bone,† but still the rational sight or the mind, which penetrates to secret recesses of nature denied to the eye, judges from the indications afforded by the forms and by all that comes to view, that the single bodies of this medulla act their systole and diastole, equally as do the brains. For here we see incisions in the form of clefts, gaping spaces, fibres continued from the brains, appendices on which are impressed forms of motion, throbbing arteries placed in the midst, interstices between the beginnings of the nerves, and a perpetual flow of animal spirits and humors. Therefore, he who denies motion to these scales and levers of the brain, he also denies life to the body; for we live as animate beings by virtue of motion, and we move by virtue of life.

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*The annular protuberance or pons Varolii.

†A name given to the sphenoid bone.

107. *The spaces between the meninges, the lateral ventricles and also the fourth ventricle, the interior sanguineous receptacles, the intercalated clefts and retiform plexuses, all give abundant opportunity for this expansion.* As regards merely the sanguineous receptacles; these present themselves to sight scattered here and there in the cerebrum and cerebellum, and also in the medulla oblongata, where, however, they are less dense. For they are, as it were, sinuses or asylums for the superfluous and worn out blood and are so numerous that, in dissected hemispheres, they present the appearance of ruddy stars. Their use is not only that they may receive any excess of blood, and may help in dilating the brains, but also and more especially that they may hold the brains to a just measure of expansion. For it is known that the brains swell in gladness, courage, and hope, but are contracted in sadness and fear; and yet in every such state induced by the affections of the animus they continue their animatory alternations. Hence the effects that follow are either stronger or weaker; hence also the cerebrum is stretched, as in wakefulness, and its beds relaxed, as in sleep.

108. *But the specific directions are as many as are the beginnings of the nerves that issue forth, and to which as to peduncles the expansory motion is determined.* For the directions of the motion are particular, specific and general, all so co-ordinated and subordinated that the particular directions refer themselves to their specific directions, the specific to their generic and these to one universal direction. The most single determinations are as many as are the fibres; the special determinations, as many as the bundles of fibres; and the general determinations, as many as the nerves. Such is the case in the annular, olivary and pyramidal protuberances; such in the striate bodies; and such also in the cerebrum and cerebellum; but all return to the common direction,—the direction of the whole encephalon,—to which all inferior directions are subsidiary and with which they conform.

109. *But in general they tend towards the medulla spinalis; in order, however, that they may suitably refer themselves to this point, they finally curve around from the anterior portion of the medulla oblongata to its posterior, towards the fourth ventricle, and thus to the posterior portion of the medulla spinalis.* This is evident from the direction of the fibres; from the transverse and perpendicular incisions which traverse the medulla oblongata in the neighborhood of the pyramidal and olivary eminences; from the manner in which the fourth ventricle and the calamus scriptorius are expanded; from the influx of the motion of the cerebellum through the peduncle; from the break in the medullary and spinal stem posteriorly, but not anteriorly, in the great foramen of the occiput and the vertebral cavity; moreover also from the exit of the nerves and, in the whole cylinder, the direction of their motions toward their beginnings; besides many other indications of which we shall speak in detail in our transactions.

CHAPTER V.

THE DETERMINATION OF THE MEDULLARY SUBSTANCE IN THE MEDULLA SPINALIS.

109a. *In the spinal or vertebral canal, this same medullary substance constitutes the circuit or periphery, while the cineritious substance constitutes the axis,—just the reverse of what obtains in the brains. Here are found longitudinal fibres, oblique fibres, and fibres that are circular and spiral; for the longitudinal fibres are fibres of the cerebrum and cerebellum extended to this spine, while the other fibres are proper to the axis itself. These fibres, mutually, as it were, banded together, make a bundle of inextricable texture, and one that cannot be resolved so long as the fibres live in consort. The last fibres terminate in a cone and pursue their course almost in a straight line; the collected bundle of these fibres is called the Cauda Equina.*

By every alternation in the animation of the brain, and also by force of its own cineritious substance, this whole medullary structure is stretched lengthwise, and expanded breadthwise. For between the integuments is a space into which it swells; at the back are cavities; and in front is stretched a longitudinal indentation. But the internal directions of the motion are as many as the nerves which are to issue forth through the cranies of the vertebræ, and to which the directions refer themselves as to their axes and peduncles; these nerves, after they have measured their course through the body, again unfold their fibres. In general, this medullary crust is so expanded and elevated that it surges towards the posterior region of the spine but not towards the anterior.

Such is the nature of the determination of the fibres of the medullary substance, the direction of the motions and active forces, and the fluxion of the spirits of the encephalon. From these, by the mediation of the nerves, organic forms and motor powers are raised up in the body, and renewed, actuated, and vivified. For according to the state of this formative substance, causes flow into their effects, and forces into their modes, suitably to the intuition and representation of the soul. Wherefore, from its very beginning, the fibre is conceived, born, bent, and determined to a use in the mediates and extremes, which is foreseen and present.

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110. *In the spinal or vertebral canal, this same medullary substance constitutes the circuit or periphery, while the cineritious substance constitutes the axis,—just the reverse of what obtains in the brains.* See above, n. 62-67. *Here are found longitudinal fibres, oblique fibres, and fibres that are circular and spiral.* That there are longitudinal fibres, and that these are interwoven with fibres running from a center in an oblique and circular direction, that is to say, spirally, is apparent from the downward flux of the fibres from the brains; namely, [1] From their inflexion,—which is fascicular when they enter into the beginnings of the nerves; almost circular in the neck; approaching to a spiral in the dorsum; becoming an elongated spiral in the lumbar region; and finally, in the cauda equina, almost a straight line. [2] From the insufflation of air, or the injection of lymph between the arachnoid and pia membranes, and also underneath the latter; for the injection flows around as though in a circle. [3] Finally, from the fact that this medulla, when exposed to the air, passes off into a humor, and when dried or boiled, falls to dust; this shows that the fibres are interwoven crosswise, and that longitudinal fibres flow into transverse diametric, oblique, or circular fibres, or, the fibres of the cerebrum into those proper to the medulla spinalis. *For the longitudinal fibres are fibres of the cerebrum and cerebellum extended to this spine, while the other fibres are proper to the axis itself.*

111. *These fibres, mutually, as it were, banded together, make a bundle of inextricable texture, and one that cannot be resolved so long as the fibres live in consort.* For, as examination shows, there are fibres which are transferred from the right side to the left, and from the left side to the right, and while they are following this course, they are decussated by other fibres which they meet. From the interweaving of the fibres which thus results, there is formed, as it were, a platted mat, which is stretched in motion, and relaxed in rest. Thus, and in no other way, are the fibres proper to the medulla spinalis held in consonance with the fibres of the cerebrum and cerebellum, and in obedience thereto; and this, in order that the latter may will and command, and that the former may inflow into the motor fibres of the body, and act.

112. *The last fibres terminate in a cone and pursue their course almost in a straight line; the collected bundle of these fibres is called the Cauda Equina.* What runs through this cone and infills it, is a purely fibrous substance distributed into quasi nerve fascicles, which, when separated from their mutual connections, exhibit the appearance of a horse's tail (*cauda equina*).

113. *By every alternation in the animation of the brain, and also by force of its own cineritious substance, this whole medullary structure is stretched lengthwise, and expanded breadthwise.* Exactly according to the direction of the fibres which are so many little canals capable of extension and expansion, for they are images of the arteries. See the comparison instituted below. [n. 119, *seq.*] *For between the integuments is a space into which it swells; at the back are cavities; and in front is stretched a longitudinal indentation.* Here we meet similar phenomena, as those noticed above in the description of the medulla oblongata. [n. 105-107]. The same remark also applies to what follows, namely, *But the internal directions of the motion are as many as the nerves which are to issue forth through the cranies of the vertebræ, and to which the directions refer themselves, as to their axes and peduncles.* [n. 108, 109.]

114. *These nerves, after they have measured their course through the body, again unfold their fibres.* The case is not unlike that of the peduncles of the cerebrum and cerebellum, concerning which we have already observed that they first gather together the scattered fibres, and then send them forth in every direction; almost like the trunk of a tree which sends out its roots on the one side, and its branches and leaves on the other. Such also are the nerves, which finally unfold themselves into organic forms, as into so many branches and twigs.

115. *In general, this medullary crust is so expanded and elevated that it surges towards the posterior region of the spine but not towards the anterior.* Compare what has been said above, n. 109. For the anterior part of the medulla spinalis adheres somewhat closely to the dura mater or thick involucrum; but its posterior is slightly removed from this covering. There are, moreover, many other confirmatory indications, as, for instance, the cavities at the back, and the corrugations of the posterior spinal arteries and veins, etc.

116. Now follows the end and use, which I simply adduce without making any comment, namely, *Such is the nature of the determination of the fibres of the medullary substance, the direction of the motions and active forces, and the fluxion of the spirits of the encephalon. From these, by the mediation of the nerves, organic forms and motor powers are raised up in the body, and renewed, actuated, and vivified. For ac-*

cording to the state of this formative substance, causes flow into their effects, and forces into their modes, suitably to the intuition and representation of the soul. Add to this the observations made in Trans. I., Chapter iii. [n. 247, *seq.*]

117. *Wherefore, from its very beginning, the fibre is conceived, born, bent, and determined to a use in the mediates and extremes which is foreseen and present.* For the fibres of the olfactory, optic, acoustic, and gustatory nerves, go straight from the bosom of their medulla as soft fibres; the other fibres are somewhat firmer, and harder, and are bound together in stouter tunics. Some, from their very first motion and step, are deeply conscious of the society into which they are to enter, and therefore, even from the womb, they at once separate themselves from their companions, and pick out an entirely different path. Such is the case with the spinal nerve,* which ascends through the occipital foramen to the eighth pair* of the head,—to say nothing of like departures in the case of other nerves, especially after they have entered the kingdom of the body, where they diligently seek out and come across companion sensory and motor nerves, to which they ever and anon adjoin themselves. Surely, no such thing would happen unless this activity and determination were impressed upon them by some superior mind which is concealed from our inferior mind, and which sends forth ministering fibres, like so many rays, for the performance of its ordinances, and the carrying out of its decisions.

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*Called also the spinal accessory nerve.

*The par vagum. The spinal accessory nerve rises from the medulla spinalis of the neck, ascends to the brain through the occipital foramen, and there joins the par vagum. In company with this nerve it again passes through the occipital foramen. It then separates from the vagus nerve and is distributed to the trapezius.

CHAPTER VI.

ON THE SIGNIFICATION OF TERMS IN NEUROLOGY.

117a. *But since the medullary substance is made up of fibres and vessels, and of other ducts emulous of the fibre and vessel, all mutually interwoven and joined together by anastomosis; and also of the various kinds of lymphs and serums which course between them; it is necessary for the science of anatomy, and here, in particular, for the science of neurology, that each of these constituent parts be given its own proper name, and that the meanings of these names be explained. That is called a Fibre which draws its origin from the cortical substance; a Vessel, which draws its origin from the heart; and a Duct, which draws its origin from a gland; or, what comes to the same thing, a Fibre is that which conveys the purest animal fluid, a Vessel that which conveys the blood, and a Duct that which conveys all other humors. The fibres of the brain are called medullary fibres, and their continuations in the body are nerve fibres. Fibres, therefore, descend from the superior kingdom, or kingdom of the brain, into the inferior kingdom, or kingdom of the heart, while vessels, on the other hand, ascend. But whether we say fibre, or vessel, or duct, they are all nevertheless little canals, because hollow and permeable. But because, in universal nature and the kingdoms of nature there exists order and degrees of order, therefore there are simple and compound fibres, simple and compound vessels, and simple and compound ducts. Therefore, by reason of composition, there are fibres of the first, of the second, and of the third order, in which respect fibres make one with vessels and ducts. Moreover, there are vessels of a middle nature, both in respect to their origin, and in respect to the fluid which they convey; these we call vessels emulous of the fibre. But motor, fleshy, muscular, tendinous, brawny, and even cartilaginous and osseous fibres, must be derived from genuine fibres, vessels, and ducts.*

On the other hand, sprigs, branches, shoots, foliage, sprouts, boughs, capillaments, cords, stamens, villi, threads, funicles, strings, stems, trunks, fascicles, and bundles, are names common alike to the family of fibres, and to that of vessels and ducts.

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118. *But since the medullary substance is made up of fibres and vessels, and of other ducts emulous of the fibre and vessel, all mutually interwoven and joined together by anastomosis; and also of the various kinds of lymphs and serums which course between them; it is necessary for the science of anatomy, and here, in particular, for the science of neurology, that each of these constituent parts be given its own proper name, and that the meanings of these names be explained.* As, for instance, what, in particular, is denoted by fibre, what by vessel, and what by the other principles and objects of the science of angiology. Anatomists use these words promiscuously, for some call a fibre a vessel, and others a vessel a fibre, each one using the terms according to the individual ideas which he has conceived respecting the things meant. Thus each one interprets the term in accordance with his understanding of the thing; and, conversely, each one explains the thing meant in accordance with his understanding of the term. Hence, from terms arise so many disputes respecting things, and from things respecting terms. But to choose suitable and simple words and to bring out the innermost meaning of these words, is impossible, except to one who has a profound knowledge of the essence and nature of the thing to be expressed. Who, pray, can give a true definition of the fibre if he be ignorant of its origin, nature, and functions? Will he not take a capillary vessel, or the ultimate ramification of some artery or vein, to be a genuine fibre?—for they are alike in tenuity and in appearance. This is the reason why the one term is substituted for the other promiscuously.

119. *That is called a Fibre which draws its origin from the cortical substance.* Add here Trans. II., n. 111-117. This signification of the term Fibre agrees also with the signification commonly accepted. For fibres are called fibres of the brain, and their continuations fibres of the nerves. Hence fibres are distinguished from vessels by the fact that each one of them enjoys its own individual origin from which it derives its particular nature. In this way, also, is the term fibre understood by the mind, which is the parent of ideas or the mistress of words. *A Vessel, which draws its origin from the heart.* Therefore it is called a blood vessel, and, in particular, an artery or vein. This nomenclature, however, causes no dispute, for it is in received usage among anatomists. *And a Duct, which draws its origin from a gland.* Hence we have secretory, excretory, lymphatic, serous, lacteal, bile, pancreatic, salivary, chyliferous, seminal and many other kinds of ducts. For the peculiar office of glands is to prepare humors of this nature, and, when they are prepared, to send them forth, that is, *educe* them, through little channels to specific and particular uses. Some, indeed, call these ductules vessels; but I think the term unsuitable because they differ from the vessel in origin, nature, and function. How manifold in the body are the origins of such ducts, may be learned merely from examination under the microscope; for in the cuticles, in the single viscera, yea, in the arteries and veins, they constitute entire membranes, which are commonly called glandular. The names given above have been drawn from the origins of the things named, but they will also be found suitable if we base our nomenclature on the fluids which they convey. And so follows the induction, *Or, what comes to the same thing, a Fibre is that which conveys the purest animal fluid, a Vessel that which conveys the blood, and a Duct that which conveys all other humors.*

120. *The fibres of the brain are called medullary fibres, and their continuations in the body are nerve fibres. Fibres, therefore, descend from the superior kingdom, or kingdom of the brain, into the inferior kingdom, or kingdom of the heart, while vessels, on the other hand, ascend.* The inferior animal kingdom is the body proper, which is built up from the blood and its vessels, and is therefore called the kingdom of the heart. In this kingdom are actions or executions, that

is to say, effects and external sensations. The superior kingdom is the brain, wherein are fibres with their animal spirit. More especially, it is the kingdom of the cortical substances, for in these is the beginning of the brain. In this kingdom are the causes of effects, and here are volitions and internal sensations. There is also a supreme kingdom, where is the purest and vital essence of the blood, and to which fibres may be attributed by eminence. In this kingdom are the beginnings of determinations, the intuitions of ends, and the first representations of things,—consequently the soul itself. Such, then, is the number of the kingdoms into which the animal empire is seen to be divided,—but to explore the mutual and reciprocal influx of the one kingdom into the other, is to explore the commerce of soul and body.

121. *But whether we say fibre, or vessel, or duct, they are all nevertheless little canals, because hollow and permeable.* But on the permeability of the fibres, even the most minute and simple, see what follows [n. 142-143].

122. *But because in universal nature and the kingdoms of nature there exists order and degrees of order, therefore there are simple and compound fibres, simple and compound vessels, and simple and compound ducts.* On the series, degrees, subordination, and co-ordination of all things in created nature, see Trans. I., Chap. viii. [n. 579, *seq.*] In that chapter I have by no means intended the simple to be understood as meaning what is devoid of all dimensions, space and extension, but as meaning every single first in the order of the compositions of each genus; for the absolutely simple must be sought for entirely outside of nature. *Therefore, by reason of composition, there are fibres of the first, of the second, and of the third order, in which respect fibres make one with vessels and ducts.*

123. *Moreover there are vessels of a middle nature, both in respect to their origin, and in respect to the fluid which they convey; these we call vessels emulous of the fibre.* For there are little channels which sometimes, like fibres, carry animal spirit, and sometimes, like vessels, carry the purest serum, almost as is the case with the lymphatic vessels or thoracic ducts, which sometimes carry chyle, and sometimes pure lymph. As regards their origin, however, these vessels spring from their own follicles, cells, vesicles, or glands, especially from the subcutaneous glands; and, on their way to the cortex of the cerebrum, they commingle with genuine fibres, besides constituting the cortical substance from which the fibres are continued. By reason of this two-fold aspect they are vessels of a mediate nature, or vessels emulous of the fibre. But what vessels belong to this class, and what their quality, is a matter for particular exposition. [See Chap. ix, n. 168, *seq;* see also *n.* 129.]

124. *But motor, fleshy, muscular, tendinous, brawny, and even cartilaginous and osseous fibres, must be derived from genuine fibres, vessels, and ducts.* All things are soft in their origin, even those matters which in time grow hard and bony; for the hard arises from the soft, and the soft which is continuous and coherent, from that which is contiguous and fluid. For unless beginnings were fluid, and thus enjoyed free power of action, their continuations could never be disposed to the will of fluids. What is compounded must be compounded of parts, and if of parts, these parts must be prior to their compound. Thus the properties that are within the concrete or the continuous aggregate, are to be ascribed to the fluidity of the parts, and to their power and nature of acting freely. This is confirmed by the mere anatomy of the embryo in the womb, and the chick in the egg, and, also, by the experience of the eye itself, which shows that motor or flesh fibres consist of coalesced vessels, fibres, and ducts, that tendinous fibres arise from flesh fibres, cartilaginous fibres from tendinous, and osseous fibres from cartilaginous,—and this by the mere force of inertia, or by the privation of active forces, that is, of vital motions. *On the other hand, sprigs, branches, shoots, foliage, sprouts, boughs, capillaments, cords, stamens, villi, threads, funicles, strings, stems, trunks, fascicles, and bundles, are names common alike to the family of fibres, and to that of vessels and ducts.*

CHAPTER VII.

THE MEDULLARY SUBSTANCE IN GENERAL.

124a. *The medullary structure of the cerebrum, using the term cerebrum in a broad sense, is made up solely of fibres, vessels, and ducts, wonderfully intertwined with each other. But the first place is held by fibres, which have their origin in the brains; for they are produced from the cortical substances as from so many most simple and perfect little hearts, brains, glands, muscular grains, or matrices. The second place is held by arterial vessels, which, passing by the cortex and continually ramifying, betake themselves to the medullary body, and there commingle with genuine fibres. There are also vessels of a middle nature, or vessels emulous of the fibre, which are taken from the tunics of the arteries and from the pia meninx, and are inserted among genuine vessels and fibres, in order that they may perform their own particular function. There are also little ducts, though few in the healthy brain, which are produced from glands that frequently come into existence, and which take on the appearance of a compound fibre. That there are so many kinds of little canals and filaments in the medullary structure of the cerebrum, cerebellum, medulla oblongata and medulla spinalis, is declared by the evidence of sight. These threads, diverse in origin, nature, and function, mutually consociate and distinctly enfold themselves into reticular plexuses.*

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125. *The medullary structure of the cerebrum, using the term cerebrum in a broad sense, is made up solely of fibres, vessels, and ducts, wonderfully intertwined with each other.* By the cerebrum, used in a broad sense, is meant, not only the cerebrum in particular, but also the cerebellum, medulla oblongata, and medulla spinalis, or all that which goes under the name encephalon; that is to say, the superior and prior part of the animal kingdom.

126. *But the first place is held by fibres, which have their origin in the brains; for they are produced from the* *cortical substances as from so many most simple and perfect little hearts, brains, glands, muscular grains, or matrices.* That genuine fibres have their origins in the brains, will, I think, be denied by no one, if he stops to consider that in the incubating chick, and in embryos, the cerebrum, using the term in a broad sense, exists before the heart, lungs, and other viscera, the pure and white ichor before the blood, and the most tender fibres, which are the first begotten, before the veins and arteries, which are compounds of the fibres. For it is plain to be seen that the fibre is emitted from the cerebrum for the purpose of framing the little machine of the heart itself, and not the reverse. Therefore, not only the motor fibres and the coronary vessels, but also the very motion of the heart, all depend on the cerebrum as on their efficient, impelling, and perpetually continuing cause, as may be seen demonstrated by abundant experience in Trans. I., Chap. iii. [n. 241, *seq.*] Therefore it is the cortex, or this corcular substance of the cerebrum, which puts forth the fibre, whence arise the nerves, arteries, and veins, from which exist all the other parts in the kingdom. That the cortex is situate in the first term of the fibres, see Trans. II., n. 111, 114, 115; that it is like a little heart, *ibid.* 132-139; that it is like a little brain, *ibid.* n. 191-196; that it is an eminent gland, *ibid.* 183-190; like a muscle, *ibid,* 176-182; like a womb,*ibid,* 190; in a word, that we may attribute to it, by eminence, everything whatsoever that performs any kind of office in the whole animal kingdom, *ibid.* 176. But the terms heart, little brain, (*cerebellum*), gland, and muscle, are all names pertaining to compounds and not at the same time to simple substances; wherefore, in order that they may, by analogy, be applied also to these latter, they are called most simple and perfect little hearts, little brains, glands, and muscles. Confer, Trans. I., Chap. viii., sec. 5 and 6. [n. 612-627.]

127. But it is of importance that I here pause a little, in the treatment of the origin of the medullary, and hence of the nerve fibre, and gather together the opinions of the learned for the sake of confirming the above point, namely, that the fibre must arise from the cortex. For the very definition of fibre and a knowledge of its nature, depends on an exploration of its genesis. The most acute investigators, such as Malpighi, Vieussens, Ridley, Willis, Boerhaave and others, confirm the point by the weight of their opinion, because experience supports it.

MALPIGHI speaks as follows: The outer portion of the cortex is covered over by the pia mater and its blood vessels, which penetrate deeply into the substance of the glands; their inner portion puts forth a white nerve fibre like a true vessel, as the lucidity and whiteness of these bodies permit us to observe. Therefore the white medullary substance of the cerebrum results from the connection and confasciculation of a multitude of these fibrils, and if the nature of the cortex may be explained by a familiar example, no better one would occur, than the structure of the pomegranate." [*sup.*, n. 19.] "Since a large quantity of the cortical substance is observed in the ventricles and at the head of the medulla spinalis, where are situated the interior prominences; and since, when these prominences are laid open, fibres are observed, which are continuations of the nerves, we must perforce conclude that the nerves themselves are also produced from these interior glands." [n. 20.] "This is undoubtedly true, namely, that every single gland of the cortex is bedewed from the extreme ends of both arteries and veins." (*ibid.*) "You will also observe the same structure in the extreme appendices of the corpus callosum; for the fibrous structures of which the arch of the ventricles is woven, finally end in, as it were, ragged fringes, or in productions after the manner of gyres, and these, not unlike the multitudinous roots of plants, are immersed and implanted in the cortex, which thus serves the turn of soil or earth." (n. 21, and Trans. II., n. 76, 78, 80.)

VIEUSSENS: "The medullary or white substance in the cerebrum, cerebellum, and medulla oblongata, is so closely applied to the cineritious substance that the two coalesce." (n. 17.)

RIDLEY: "I should take these ultimate vessels to be nothing else than the numerous still further capillary productions of the cortical vessels. (n. 18.)

Willis: "Its parts, in respect to the encephalon and the medullary appendix, are like a branching shoot, growing about the trunk of a tree, that is, if we take the cortical substances of the cerebrum and cerebellum as the roots, and the whole medullary substance as the stem and bark." (n. 5.)

Boerhaave: "The outer, cineritious, [soft], and more humid substance is called the cortex of the cerebrum and cerebellum. It everywhere closely invests the entire origin of the other substance, which is within, is extremely white, more solid, and less juicy, and is called the medulla of the cerebrum and cerebellum. It is clearly manifest, therefore, that the latter everywhere first arises from the former, both in the appendices, the ventricles, the crura, and the medulla oblongata. But in the interior of the medulla spinalis, on the other hand, is found a substance similar to the cortex, being in like manner wholly arterial; but it is here surrounded by the medullary substance, which is just the reverse of what obtains in the former case. In the cerebellum, these two substances are so conspicuous that the manner in which the medulla proceeds from the cortex, and the distinction between the two, their proportion, and fabric, can all be clearly discerned. It can also be seen that the cortex here is always harder and more yellowish than the cortex of the cerebrum." (n. 45.)

If we contemplate the cortex when exposed in living brains,—examining it either through the lens of a microscope or in a drawing from life,—we shall plainly see how the fibre proceeds from it, springing forth like a rivulet from its fount. The same is also confirmed in the case of those afflicted with hydrocephalus, apoplexy, catalepsy, paralysis, mania, convulsions, and cynic spasms; for in such persons, as shown by post mortem examination, the disease of the cortical substances is derived into the fibres continued therefrom, and, finally, into the muscular fibres; whence arise the meaningless actions and motions. Moreover, the physiological phenomena of the [animal] kingdom also [add their confirmation by showing] that, in the cerebrum, exists a last and a first,—a last, to which sensation tends, and where it unfolds itself, passes around, and looks about; and a first, from which activities flow down into the motor fibres of the body, whence arise actions; and this, in order that the last of sensations may be in that place where is the first of active forces. And because the cortical substance is the parent of the fibre, it therefore follows that it is in this, its own substance alone that the brain begins to be a brain; for here is the receptacle of sensations, or the common sensory, and, together with it, the beginning of actions, or the common motory. For this reason a gyre, or rather a turning, is set up, namely, from sensation to perception and from perception, by means of the will, to action.

128. *The second place is held by arterial vessels, which, passing by the cortex and continually ramifying, betake themselves to the medullary body, and there commingle with genuine fibres.* These vessels are not indeed fibres, since they take their origin only from the heart; yet they can be distinguished from genuine fibres only with the greatest difficulty; for they are of almost the same dimension, pellucidity, and whiteness. But that they differ in nature and function, will be demonstrated in the following pages. That the carotid and vertebral arteries, mounting up from the kingdom of the heart, approach the cerebrum and enter into it, is sufficiently evident from anatomy; for they compactly insinuate themselves through the single fissures and into the well-nigh labyrinthine anfractuosities, and, by their mutual apposition and conglomeration constitute membranes, or a kind of vascular flesh. In this way they frequently penetrate into the beds of the cortex, or, passing the cortex by, immerse themselves in the medullary lake, and this in such number that it may be doubted whether the medulla is not a mere continuation of the arterioles without the intervention of any new substance, that is, of any cortical substance. But that the little arterial twigs penetrate into the medullary nucleus, and become the second constituent of that nucleus,—and this without that rebirth which takes place when they go into new cortical spherules,—is a matter that ought to be decided by experience alone. Let us therefore hear the anatomists:

MALPIGHI confirms it in the following words: "In the mass of the cerebrum and cerebellum we found remarkable and numerous ramifications of arteries and veins,—such certainly as are to be met with nowhere else in the body; yet in such a way that the trunks of the arteries were not always accompanied by veins; this we have especially observed in fishes. In the more perfect animals, therefore, it is clear that the blood-vessels, by means of the meningeal membranes, irrigate the extreme glands of the cortex, of which the cerebral gyres are composed, and that their offshoots penetrate to the inmost parts of these cortical glands." (n. 20.) "Nor are there wanting blood vessels, by which, indeed, the whole substance of the cerebrum is pervaded; for if we institute a comparison with the whole body, we shall find at least a third, if not a half, of the blood is carried into the head." (n. 21 *sup.* Trans. II., n. 78.)

LEEUWENHOEK: "Throughout this clear matter, and these globules were scattered a great number of extremely minute blood vessels, which, when laid over each other three or four deep, without any other interjacent material, were likewise distinguished by their red color," etc. (n. 22; Trans. II., 71.) "Examining a sheep's brain, I likewise found in the cortical parts a vast number of the most delicate blood vessels. I have often seen this incomprehensible multitude of exquisitely minute blood vessels with my own eyes; and I saw almost every single vessel again splitting into lesser branches," etc. (n. 24; Trans. II., n. 73.) "When we gently separate the deeper parts of the cortex, lying in the middle region of the cerebrum, from the medullary parts, we see between them so great a number of little blood vessels, as to make an entire membrane. In addition to these fine blood vessels, there are, in the cerebrum, still other vessels of such fineness, that, in my judgment, no round corpuscles could permeate them, even if it were divided into more than a thousand parts. I say nothing here about blood vessels which equal or excel the thickness of a hair of our head." (n. 22.) "In all my observations, enumerated in these pages, I pass by without mention the innumerable blood vessels running through the cerebrum, which can be seen in the dissected brain with the naked eye; for they are like entire rivers when compared with the little vessels spoken of above, which latter must be esteemed as the merest rivulets, brooks, and rills." (n. 25.) "When I set the structure of a pig's brain before my eyes, I had no difficulty in concluding that there must be a certain connection between the blood vessels and the particles of the brain, in order that the latter may be preserved, and may maintain their vitality by a perpetual inflow of blood; for in the bodies of animals where this is lacking, corruption must necessarily set in." (n. 36.) Consult the author's figure, [*sup.*, n. 38, fig. 13], where he delineates a blood vessel lying in the midst of the cerebrum, which he thus describes: "I placed under the microscope an extremely fine particle of the cerebrum, in which appeared an incredible multitude of blood vessels cut transversely and at right angles; indeed, all the parts designated in Fig. 13 by the letters OPRSTVW, even to the very dots, are nothing but blood vessels. Y and Z designate two larger vessels, containing clotted blood." (n. 38.)

The stupendous ramifications of the arteries of the cerebrum, their discerption, and their consequent abundance, are depicted in a figure by Ruysch, who, by his peculiar method of maceration,* separated and unravelled the little stems which are continuations of the arteries, by loosening their connections, and thus brought to view the immense multitude of vessels penetrating the cerebrum. ([n. 53-55], Trans. II., n. 87.) This anatomist gives reason to believe that the cortical substance is not glandular but vascular. (n. 57; Trans. II., n. 86). But this dispute about words is easily settled if we reflect on the origin of the cortex, and on its progress into the fibre; for each single spherule, vesicle, or gland of the cortex arises from a certain vascular termination, and from this it progresses into a fibre. The fibre, therefore, is a continuation of the vessel, with the cortex interposed. Confer Trans. II., n. 110, 111, *seq.* Thus there is nothing in the cortical gland that is not vascular, according to the opinion of Ruysch, and there is nothing in this vascular expanse that is not glandular, according to the opinion of Malpighi, who says: "This is undoubtedly true, namely, that every single gland of the cortex is bedewed from the extreme ends of both arteries and veins." [n. 20.] Confer, [n. 19, 20, 23, 24, 25, 45, 57, and] Trans. II., n. 12 [?72], 73, 74, 76, 78, 80, 85, 86, 91, 111-116.

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*For a description of this method, see 2 E. A. K., n. 86.

The above considerations make clear the distinction between fibres and vessels. The former, although they are continuations of arteries, with the cortex interposed, greatly differ from vessels in their nature, that is to say, in their force, and their manner of action; for from a new origin, they derive a new genius,—on which matter see what follows. By vessels, therefore, we mean, not only the arterial shoots implanted in the cortex, or which build up the cortex, but also those which, passing the cortex by, pour themselves into the medullary nucleus. In this way, I believe, one may understand what the fibre is, and what the vessel, and, moreover, that in the structure of the medullary part of the cerebrum there is more of what is vascular than of what is fibrous. For the vessels are continually ramified, and thus occupy a great deal of space; but this is not the case with the fibres, for these cannot be ramified. This seems to have given the ancient philosophers, such as [Aristotle], Alexander, Averroes, and Apono,* the basis for their opinion that the nerve fibres arise from the heart; and it seems also to have given Praxagoras, and, among modern authors, Cesalpin, Reusner, Hoffman, Martian, and also Willis, the basis for their opinion that the nerves are nothing else than continued veins and arteries, (n. 12.)

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*The Alexander referred to is probably ALEXANDER OF TRALLES (525-605), a Byzantine physician who is said to have been the greatest of medical authors since Hippocrates. AVERROES (1126-1198), was a Spanish philosopher and physician, reckoned as the most advanced Aristotelian of his age. APONO (1250-1316), was an Italian physician and Aristotelian, celebrated as a translator of Hippocrates and Galen. In adducing these authors, and also those that follow in the text, Swedenborg is quoting from Bartholin, who states that, while Alexander, Averroes and Apono agreed with Aristotle that the nerves arose from the heart, they added that this origin was by means of the brain. See n. 12.

ARISTOTLE'S words are: "In all blood animals, the principality of the senses is in the heart, for in the heart must we necessarily place the common sensory of all the sensories." (*De Juventute et Senectute* iii., 23.) "Some suppose that the power of sensation has its seat in the cerebrum." (*Ibid.*, 35.) "Therefore, in blood creatures, the soul, as it were fiery, is in the heart, and in bloodless creatures, in some corresponding part." (*Ibid.*, iv, 14.) "For, in animate creatures possessed of blood, the heart is what is first begotten; this is evident from the things which we have seen in such creatures, while they were still coming into being. (*Ibid.*, iii., 7.)

But in that age, when experience was slight, being, as it were, in its infancy or cradle, it does not seem to have been known that the cerebrum exists before the heart, or that, first of all, are produced fibrils, then vessels of the purer blood, and lastly vessels of the red blood; and that the one precedes the other, and then, as they are compounded, acts with it. See Trans. I., Chap. iii. [n. 241, *seq.*, especially n. 249, 270-278.] Nor does it seem to have been known that from the abundant corcular substance of the brains proceed fibres, which furnish natal gifts, not only to the heart, but also to all the other members of its kingdom, and this, in a manner ordained, in order that vessels may return to their parent cortex, and may apply themselves therein that thus the circle of life may be completed. Therefore fibres descend from the superior region of the kingdom into the inferior region, or into the body; but vessels ascend from the inferior region, or from the kingdom of the heart, to the superior region; and both are united in the cortex. The cortex, therefore, looks both backwards and forwards, that is to say, to the vessels that approach, and to the vessels that depart; thus in the effect it regards the cause, and in the cause, the effect. But, as these matters are somewhat remote from the senses, and are therefore still slightly obscure, I shall endeavor, in the following pages, to render them more clear, and to explain them.

129. *There are also vessels of a middle nature, or vessels emulous of the fibre, which are taken from the tunics of the arteries and from the pia meninx, and are inserted among genuine vessels and fibres, in order that they may perform their own particular function.* See above, n. 123. That stems, as it were vascular or fibrous, are taken from the tunics of the arteries, and also from the pia meninx, seems to have been first detected by the glasses of Leeuwenhoek. This anatomist calls them fibrils,—but it is better to quote his whole description. Consult figs. 8, 9, 10, 11, 12 [see above, n. 36-38]. "In fig. 8, ABCDEFGHIK designates an extremely minute portion of a pig's brain,—the particle BCDEF lying quite close to the meninx. AB, KC, ID, HE and GF, designate blood vessels which, immersing themselves more deeply into the cerebrum, escaped the sight; for the few and scattered blood globules which flow through them have not enough redness to make the vessels visible. Those particles that are interjected lengthwise between the blood vessels, and are, as it were, continued from them, we have rightly called fibrils of the cerebrum. These fibrils which have hitherto escaped my sight, are shown as cut, not straight across, but obliquely. In the same figure, ML denotes the ruptured particles of the above mentioned fibril." (n. 36.)

"In Fig. 9 the letters NOPQRS denote only a very small part of what we saw through the microscope; and it is delineated merely to exhibit to the reader the membrane, PQR, which covers the cerebrum. The artery, NQ, seen in the middle of the figure, to which, on both sides, are joined fibrils of the cerebrum, is much thicker in the middle than at the extremities N or Q. The reason is, because the fibrils seen between NOP and NSR have so contracted or shrunken, that they have torn the artery; the middle portion of the latter, therefore, bulging to both sides, is necessarily thicker. Moreover, I placed under the microscope a minute portion of these fibrils of the cerebrum of which I had happily succeeded in making a longitudinal section. They are shown in fig. 10, by ABCDEF. These fibrils exhibit to the sight four of their sides; indeed at one time I saw a fibril furnished with six sides. Hence follows the conclusion that one fibril consists of a number of fibrils. The fibrils shown in the figure were not taken from the neighborhood of the meninges, but from about the very centre of the cerebrum, and they consist of such minute particles, that you cannot recognize any shape in them. These cerebral fibres are, I suppose, covered with delicate little membranes, which because of their extreme minuteness never bare themselves to our sight. But unless we suppose their existence, how can we account for the separation or distinction between the fibrils which our eyes behold? This minute portion of the cerebrum was so shrunken, that in two places, BG and BH, the cerebral fibrils were ruptured. I therefore conjecture that those fibrils had been connected with each other by little membranes. A second rupture of the fibrils is seen in the same figure at IK and IL, where we see fibrils connected with the fibril I, and, above KL, with other fibrils also. What we see in the neighborhood of A and F are particles which lie enclosed in the cerebral fibrils and which have been laid bare by the scalpel, or by the incisions of the scalpel. When we see the fibrils of the cerebrum disposed in this manner, and when, at the same time, we contemplate the fibrils shown in Figs. 8 and 9, we must consider it as established that the blood vessels delineated in these figures were cut lengthwise exactly along the line of their channel, and that the cerebral fibrils were cut across obliquely, so that to our eyes the latter appear incomplete. If now we reflect on the softness of the particles of which the cerebrum is contextured, and on the necessarily fragile nature of the parts that clothe the cerebral fibrils, we can readily imagine how that those parts would never become visible to human eyes. But the above mentioned fibrils of the cerebrum, though conjoined with blood vessels in the manner just mentioned, and receiving from them their increase and nourishment, are yet by no means offshoots of these vessels, for I hold that these fibrils are not posterior in origin to vessels" (n. 37).

"When I again secured the brain of a pig, I at once removed the investing membrane, and placed some parts of the cerebrum under the microscope. Examining them with the closest attention, I found fibrils of the cerebrum contiguous to the meninx; but, as far as I was able to distinguish by sight, they showed a preference for the round rather than the quadrangular figure. I have often made longitudinal sections of the fibrils of the cerebrum where they are adjacent to the meninx, and, finally, I was fortunate enough to successfully place them so dissected under the microscope without a break. I at once had them drawn, and they are shown in fig. 11, by ABCDEF, CDE denoting the membrane investing the cerebrum. Where these cerebral fibrils are stretched lengthwise, they are rendered uneven by a number of rugosities, which the artist has imitated as accurately as he was able. The gap between A and D is caused solely by this corrugation, whereby some of the fibrils are drawn apart from each other. I afterwards tried to so separate the fibrils of the cerebrum from each other as to see both their thickness and their breadth; but, in the process, they were, in part, broken into minute fragments. I placed the largest of these fragments, although it also was broken, under a higher powered microscope, and, in fig. 12, I have had it designated by GHIKLMN. The rupture of this portion is seen in two places, namely, HI and KL. The blackish color, marked MN, denotes the thickness of the fibril. As regards the flexures seen in the same place, I am unable to say whether it was I who made them, or whether they were caused by the pressure of adjacent parts. I take it that these fibrils of the cerebrum are easily four times thicker than the flesh fibrils of the ox" (n. 38).

Concerning vessels of stupendous fineness, which were detected in the cerebrum, see Leeuwenhoek's entire description,

n. 22 above: and concerning the two kinds of fibrils, see n. 26.

As regards fibrils of a middle nature, they do not seem to have been seen as simple fibrils, but only as fibrils somewhat compounded and confasciculated, not unlike the chords of Willis in the sinus of the falx, whose roots are drawn from the interior tunic of the sinus, [see n. 2]. So also the above mentioned fibrils, which, however, are drawn from the exterior tunic of the artery. But the nature of these fibrils will be better gathered from a description of their function.

130. *There are also little ducts, though few in the healthy brain, which are produced from glands that frequently come into existence, and which take on the appearance of a compound fibre.* As to what vessels are called ducts, see above, n. 119, namely, such as proceed from glands and carry a humor other than blood. Glands of the kind from which these ducts are extended ought not to be confounded with cortical glands, for they are of a different genus, order, and nature. The cortical glands are produced from vessels of a middle nature, but these are produced from true vessels. The former are natural, for without them there would be no brain, but the latter are abnormal, nor are they seen except in a brain that is diseased and whose vigor has been weakened. For as soon as the contiguity of the parts, and the ratio of the just tension, begins to be difficient in any of the recesses; or as soon as the medulla begins to gape with undue fissures, some glandular corpuscle is immediately interposed which not only fills in the space, but also restores tone and situation to the other threads, and at the same time absorbs noxious humors and carries them off through ductules. Such glandular excrescences are found in the fabric of the sinuses of the dura mater, and even outside the sinuses between the meninges, and also in the pia meninx itself, and in the choroid plexus and elsewhere, as has been frequently discovered in the body when laboring under such sickness. But they are rarely found except in brains weakened by old age, or relaxed, and, as to their interior connections, dissolved by [cerebral] dropsy. Without these helps to support their feebleness, such brains, wholly impotent of action, would soon waste away, or die. It is my belief that it is glands of this kind that LEEUWENHOEK mentions, where he says: "I attentively examined with eyes and mind, the white or medullary parts of the cerebrum, and especially those that tend towards the beginning of the dorsal medulla, and, as I judge, I there found what appeared to the eyes to be oily globules, large and translucent as it were, surrounded by, or lying in, an ineffable multitude of the most delicate little retiform vessels or lines, mingled with a number of coarser vessels; which latter took a straight course, and were remarkable for their pellucidity" (n. 24). "Having turned my attention to the globules in the medullary part of the cerebrum, I began to consider as to whether the minute blood vessels emerging from the cortical parts of the cerebrum are not again dispersed into fine twigs of the same kind; and whether many of these twigs do not, as it were, embrace these globules or, yield to the globules. This my opinion,—that many of the irregular globules were surrounded by vessels,—was strengthened when I saw that many of the above mentioned vessels were clear in the middle, and carried at both sides a somewhat darkish appearance; and still more when I found, lying in the ruptured globules, many fine fibrous parts, which, as far as appears, are vessels" (n. 23).

But because glands of this kind are not met with except in brains wasted by some disease, I again warn the reader that he must be careful not to assume for such glands the genuine cortical glands which are immersed in the medullary part of the cerebrum and in its indrawn recesses in great abundance; nor can the sight distinguish between them, any better than between fibres and vessels. And yet an immense and intrinsic difference obtains between them; for the greater the abundance of the cortical glands, the healthier is the state of the brains; but the greater the abundance of glands of this kind, the weaker in health and the more oppressed are the brains.

These glands of the cerebrum should therefore be denominated false glands, and their ducts spurious fibres. How prone and ready nature is to fabricate such glandular structures, and thereby to restore things that are fallen and that are about to fall,—and this especially in the body—is sufficiently evident from anatomy. But to proceed, *that there are so many kinds of little canals and filaments in the medullary structure of the cerebrum, cerebellum, medulla oblongata and medulla spinalis, is declared by the evidence of sight.*

131. *These threads, diverse in origin, nature, and function, mutually consociate and distinctly enfold themselves into reticular plexuses.* On the nature of the vessel as compared with that of the fibre and on the function of each, and also on vessels emulous of the fibre, we shall speak in the following pages. By way of preliminary, we content ourselves with the observation, that fibres, mutually consociated with vessels, go off into mere plexuses like networks, the smaller within the larger; and that the medullary structure itself is a series and concatenation of such plexuses. From the determination of the fibres it is evident that each single fibre, whencesoever derived, is eagerly bent upon the performance of its own particular function in the body; and therefore the fibres decussate neighboring fibres and those that they meet; they ride over them, embrace them in anastomosis, desert them, and again touch them and inosculate.

On this subject VIEUSSENS speaks as follows: "The medullary substance may be easily divided into those innumerable fibrils, of the mutual connections whereof it is made up," and "it consists of somewhat long fibrils, variously inflected, which are so enfolded in each other, and so intercommunicant, that they produce the appearance, as it were, of a spongy body" (n. 17).

And MALPIGHI: "The fibres of the cerebrum are long drawn out. They are not parallel, but repeatedly meet each other; and we see them gathered together into a fascicle, then again separated, and afterward riding over other lateral fibres, so that they present the appearance of a loose network. This is best observed in the shark or dogfish" (n. 21). "For it is nature's accustomed way, especially at the ends of vessels, to form a network, as we find is the case in the extreme ramifications of arteries and veins; and, if we may add confirmation from an analogous example in plants, there are not wanting exactly similar structures in the fibres that compose the bark of the vine, and of other trees and plants," etc. (n. 20.)

And LEEUWENHOEK: "When looking at the medullary parts of the cerebrum it often appeared to me as if I were looking at a fishing net, the threads or cords of which could be easily stretched; and that between each aperture of the net there lay a somewhat flexible piliform body" (n. 23). "I noticed fibrils which were joined together at one point, and then, at another, diverged from each other, and a little later again united; and if I remember right I have observed similar conjunctions in the muscles of a heart taken from a certain animal. In order to make this clear as far as possible, I have had delineated an extremely minute particle of the cerebrum as seen under the microscope. It is shown in fig. 14 by ABCDEF, where CD are fibrils of the cerebrum, disjoined from each other, then coming together, and again diverging, but once more returning to the union at I, and still again at H. I have observed these alternations of conjunction and secession also in other places. Moreover, I placed under the microscope a ruptured particle of a cerebrum, designated by KLMNOPQR in fig. 15, where we see two fibrils digressing from each other at the letter N, and at once associating with other fibrils. Such consociations of fibrils can also be seen in other fibres." (n. 40.)

When this medullary structure is laid out or unfolded into a plane or membrane, nets like those of the fowler come manifestly to view; as is the case in the membrane that lines the roof of the ventricles, and also in the corpus callosum, and in the pia meninx itself, and elsewhere. These networks, of which the cerebral medulla is contextured, appear girt about with the softest little membranes,—perhaps, lest the humor running through the intercepted spaces lacerate the subtle plexiform texture, and a grosser liquor penetrate its interiors with ungrateful matters. But let us now to the use.

132. *Whence arises a structure, loose, spongy, pervious to lymphs, bibulous, soft, capable of expansion, free to act, and suitable for building up the nerves.* But let us take these characteristics one by one. It must be *loose* and *spongy,* since it is a perpetual network woven of the finest little stamens, or a plexus in a plexus; by virtue whereof it suffers itself,—not unlike a woolen, downy, or spongy substance,—to be compressed into the smallest mass. This also actually happens in the brains, for almost the entire medulla of the cerebrum, and also of the cerebellum, is compressed into a peduncle; which would never be the case, unless its structure were loose like a sponge, and, in the meantime, were steeped with humor. *Pervious to lymphs.* There are also yawning spaces between each plexiform figure, which can be expanded and constricted in diverse ways, as may be gathered from Leeuwenhoek's figure described just above. That these little spaces communicate with each other, and that together they tend towards exits provided by nature, where they may lay down their phlegms, cannot, I think, be doubted; for a humor is perpetually passing through them, which is purer and more refined towards the origins of the nerves, but grosser and more feculant at the mamillary processes, etc. Hence it follows that such texture is *bibulous* and *soft.* Also that it is *capable of expansion;* for the little spaces are so many, as it were, least ventricles, hollows, or potencies of dilation and constriction. And, therefore, since there are so many ventricular fissures or yawning commissures, there is nothing to prevent the medulla being expanded both in particular and also in general, and breadthwise and also lengthwise. In this and in no other way, as we have frequently pointed out above, could it be formed in motion and for motion. Now since the whole medullary mass is expanded at every alternation of the brain's animation, it follows that at each such expansion it sucks in, transmits, and expels new juices. *Free to act.* For howsoever the form of the motion in the brain is varied, as, for instance, whether the

force of its expansion be determined towards the interiors, or the exteriors, or in some other direction. still a mass that is so configured will yield in whatsoever direction it pleases, and will accommodate itself to every mode without danger of disruption. Meanwhile, in natural subjects, the criterion of freedom consists in this, namely, that the parts in their compound, approach more nearly to the nature of a fluid, and that they are set more loosely or sparsely. For the compound or general is then left to the freedom of its simples or parts, entirely according to the nature of the action of these simples or parts. It would be otherwise if the parts or simples were more closely connected together, as is the case in the peduncles and nerves. For there, fibre is bound and, as it were, chained to fibre, and they are held together by coverings or membranous bonds, and thus obligated to some particular mode of action. It is otherwise in the brain, and this is the reason why the first stamens are so soft as to be almost fluid, as in the embryo and infant; and why, in process of time, they acquire a harder consistency, which is the same thing as growing old. *And suitable for building up the nerves.* For in the nerves it is forced and confined to some particular form of action; not so, however, in the brains, from which it inflows through the nerves into the mo'tor fibres, or into the actions designated by the brains; for the cause must be free to act, in order that the effect may go forth. Moreover, unless the medullary substance, which is continued into the nerve substance, were everywhere patulous, porous, and filled with little cavities, the spirits could never run through it, nor the other liquors transpire;* and thus the nerve, deprived of its vital juice and incapable of action, would most certainly fail in its extremities, and thereby the correspondence of the extremities [with the beginning], and the commerce between brain and body, and also subservience, would be destroyed. *But that these things may be treated of distinctly they must be taken each by itself.*

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*Literally, "breathe through." The word is used to designate the passage of humors through pores. See n. 142, note.

CHAPTER VIII.

THE NATURE OF THE VESSEL AS COMPARED WITH THE NATURE OF THE FIBRE, AND THE FUNCTIONS OF EACH.

132a. *From the cortex we learn the nature of the fibre, and from the fibre the nature of the cortex. For the fibre derives its origin, nature or force and mode of action, essence, form, in a word, all its state and genius from the cortex; since the fibre is a production of the cortex, that is, its elongated appendix. Likewise from the heart we learn the nature of the blood vessel, especially of the arterial vessel, and from its vessels the nature of the heart. And because each spherule of the cortex is like a heart, and consequently each fibre is like an artery, therefore, from the heart we also learn what is the nature of the cortex, and from the artery what the nature of the fibre. And if anything be lacking, we are instructed concerning the nature of both from their forms, forces, and modes of action in their extremities; that is, from the universal anatomy of the body and the pathology and physiology of both body and animus. The comparison therefore teaches us: that since an artery is the continuation of a vein with the heart interposed, therefore a fibre is the continuation of a vessel of the brain with the cortex interposed. Thus, as the vein by means of the heart, is reborn an artery, so the vessel, by means of the cortex, is reborn a fibre. As the vein, when reborn an artery, entirely changes its nature, so likewise does the vessel of the brain when reborn a fibre. Hence, as the vein in respect to the artery is passive, and the artery in respect to the vein active, so the vessel in respect to the fibre, and the fibre to the vessel. And because veins and arteries undergo this mutation by the mediation of the heart, so vessels and fibres undergo mutation by the mediation of the cortex. But as soon as the artery of the body enters the threshold of the brain, that is, into the cranium, it frees itself from the empire of the heart and subjects itself to that of the brain; and hence* *it transcribes its active nature into a certain passive nature. By reason of this the arterial vessel of the brain, again become like a vein, is rendered passive in respect to the fibre, which is most highly active.*

The comparison which has been instituted, further teaches us, that as from the left ventricle of the heart a cavity is continued through the middle of the artery even to the last ends of its ramifications, so a little sinus or the minute chamber of the cortical spherule is continued through the middle of the fibre. So that every medullary fibre of the brain and nerve fibre of the body is pervious and transpirable, or is gifted with a cavity, that is to say, is a little canal, not unlike the arterial canal.

In addition to experience, reason also dictates the same thing; for without a fluid in the fibres nothing whatever in the animate body could derive and carry on its origin, progression, order, law, motor force, light, life and sensation; since a fibre without a fluid is a stem impotent of action. Moreover, as the muscular surface of the heart is transmitted by continuity into the surface of the artery, so the surface of every part of the cortex is transmitted around its fibre.

From the above considerations come the following conclusions: As in every point of the artery there is a likeness of the heart, so in every point of the fibre there is a likeness of the cortex. For from the origin of their motion or touch, both actuate their enclosed little stream into the things that follow. As the artery, into whatsoever gyres it be flexed and turned. yet drives its fluid even to the extremities; so the fibre, in whatsoever manner it be flexed and turned.. As the artery drives its blood forward by a mode of undulation, whence arises the pulse; so the fibre drives its fluent spirit by a species of superior undulation, or by modification. Thus every wave expelled from the first starting point of motion is present, not actually but potentially, in its latest goals. As the blood running through the arteries is borne along in a steady stream and with increased celerity; so the fluid through its fibres. As the tunic of the artery is formed to the nature of its blood; so the tunicle, or most delicate surface of the fibre is formed to the *nature of its fluid. Thus the tunic and its enclosed fluid constitute one vessel and act as a single cause. Hence, as the circulation of the blood is carried on through the arteries by the active and reactive force of their muscular tunic; so the circulation of the purer fluid through the fibres by the active and reactive force of the enclosing tunicle. As the artery, distended with its blood, is stretched lengthwise, and at the same time breadthwise; so the fibre traversed by its fluid. As the artery flows from the heart into the motor fibres of the muscles; so the fibre flows from its cortex into the same motor fibres, but at unlike moments; whence arises action and reaction, and, from this, alternate and reciprocal motions. As in the arteries resides strength; so in the fibres resides the force of forces and the life of the body. In a word, as the artery is continually striving to constrict itself, or to contract to its least diameter; so also the fibre. But the fluid, emitted and injected alternately by the heart and the cortex, holds both expanses. Thus the artery and fibre are continually balanced between a state of the highest constriction and of the highest expansion, that is, between death and life. Therefore, by the animations of the brain, the respirations of the lungs, the systoles and diastoles of the heart, and the circulations thence arising, there is a continual renewal of life.*

But between the arteries and the fibres there is a difference of velocity and perfection, or of moments and degrees, according to the laws of the doctrine of order. The ratio of the conformity of the artery and the fibre is gathered from the conformity of the fluids contained in them; for through the artery runs the red blood with its accompanying serum, and through the fibre the purer essence of the blood, or the animal fluid; which two mutually correspond to each other. But they differ in the following particulars, namely: that to all the arteries is prefixed one great heart; but to each and every fibre so many little hearts. Also that the arteries are continually ramified, but not so the fibres. Moreover, that in its extremity, the artery goes off into a vein; but not in the same way, the fibre. And, finally, that the circulation of the blood through the arteries is distinguished by the pulse; but not so the circulation of the fluid through the fibres.

From this comparison we may be allowed to judge concerning the use of the vessel and the use of the fibre in the brains; that is to say, because the vessel, in respect to the fibre, is of a passive nature, and the fibre, in respect to the vessel, is active, that therefore, every compound part of the cerebrum, small and large, is made up of fibres, that is, of active parts, and at the same time of vessels, that is, of reactive or passive parts. And thus that the vessels constitute the surface of the compound part, while the fibres constitute its body.

Hence, arises a natural tempering and a limited extension of forces; and a series is born, wherein the centre is regarded by every point of the surface, and the surface by the centre,—a series which limits the inseated forces to within a determined sphere of activity, and sustains, coerces, weighs and governs them. In this way, vessels are present everywhere in the medulla of the cerebrum; from which it follows that wherever a fibre or active force is lacking or begins to be lacking, there the vessels raise up a new cortex or cineritious substance (from which spring forth new fibres or new forces), according to every ratio of composition in the beginnings of the nerves, and according to the use in their extremities.

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133. *From the cortex we learn the nature of the fibre, and from the fibre the nature of the cortex. For the fibre derives its origin, nature or force and mode of action, essence, form. in a word, all its state and genius from the cortex; since the fibre is a production of the cortex, that is, its elongated appendix.* The cortex does not beget and bring forth the fibre as a parent begets and brings forth some new offspring, but it produces itself into the fibre; for, separated from the fibre, the cortex, howsoever great its potency, is an ens without any determination into act, like a brain torn away from its body. That both together constitute a unanimous body is known from the fact that the cortex sensates whatever touches and strikes the fibre, and that the fibre does whatever the cortex determines. For the cortical substance is the real brain, or the common sensory and motory.

134. *Likewise from the heart we learn the nature of the blood vessel, especially of the arterial vessel, and from its vessels the nature of the heart.* This you will see confirmed everywhere in our first Transaction on the Blood and its Heart and Vessels.

135. *And because each spherule of the cortex is like a heart,* see Trans. II., n. 132-139, and elsewhere throughout, *and consequently each fibre is like an artery, therefore, from the heart we also learn what is the nature of the cortex, and from the artery what the nature of the fibre.* By this syllogism or series of consequences, we conclude with certainty that the indications afforded by the one member when theoretically examined, will lead us to the knowledge of the other; as in the present case an examination of the heart into a knowledge of the cortex; for there is a connection of all things from their causes, which are simple and single. The primitive little heart of the body, as is plainly seen in chicks and embryos, is not unlike a spherule and form such as is that of the cortical substance in the brain. The fact that the little heart of the body increases to its dimensions and amplitude, does not prevent the likeness of the one still remaining in the other. The mass into which the heart of the body grows must in all respects correspond to the extension of its action or circulation, and to the gravity of a grosser fluid, that is, to the resistance of the blood; for nature is perpetual in her measures and modes.

136. *And if anything be lacking, we are instructed concerning the nature of both from their forms, forces, and modes of action in their extremities; that is, from the universal anatomy of the body and the pathology and physiology of both body and animus.* There is not a single thing in the animate body that is not compounded and formed from a first and simple stem; for effects flow from efficient causes, while the modes of action in the effects are the phenomena with which animal pathology and physiology abounds. If now the efficiencies of things in the living system reside in the cortex, it follows that all the single effects conspire to reveal the nature of the cortex. This is also confirmed by the doctrine of

Order and Degrees,* which shows that aggregate entities of any given degree and series, refer themselves to their unities as to their most simple parts, (Trans. I., n. 629, 630); and that from the form, nature, and mode of action of such aggregates, we may know what is the form, nature, and mode of action of the parts; and therefore that a general and particular experimental knowledge of the things which at any time touch a sensory, points out the essence of the least things of the same degree, (*ibid.* n. 631); yea, of corresponding things which are still more simple, or, of superior degrees, (*ibid.* n. 632). But let us come now to a closer comparison such as you will see commenced in Trans. I., n. 472, 570.

137. *The comparison therefore teaches us: that since an artery is the continuation of a vein with the heart interposed, therefore a fibre is the continuation of a vessel of the brain with the cortex interposed.* Concerning the artery see Transaction I., n. 130-133, and Ch. vii, on the Motion of the Adult Heart, [*ibid* n. 460 *seq.*]. For both vena cavas flow with their blood into the right auricle and ventricle of the heart, and when this blood has been passed through the lungs, it returns into the left heart. The right heart therefore is the venous heart and the left the arterial heart. But in the embryo, where the pulmonary tubes have not yet been opened, the venous blood is transferred by a quicker path, namely, by the foramen ovale and the ductus arteriosus into the left heart and the aorta. Thus the artery is wholly continued to the vein, with the heart interposed. I do not here dwell on the reasons why the continuation of vein into artery is closer and, as it were, more immediate in the embryo than in the adult, for in the latter, the blood is forced through the lungs, which are the two appendages of the heart, before it is returned towards the left or arterial heart. Now as regards the parts of the cortex: that they are continued from vessels or arteries,

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*The doctrine of "Series and Degrees" is expounded at some length in 1 E. A. K., 580, *seq.;* in 2 E. A. K., 350, it is called the doctrine of "Order and Series," and in 2 E. A. K., 210, the "Doctrine of Order."

that is, that they are set in the last term of the arteries and the first of the fibres, has been shown in Trans. II., chap. ii, [n. 69 *seq.*], and also confirmed by the most indefatigable and skillful anatomists, Malpighi, Ruysch, Vieussens, Ridley, Boerhaave and Leeuwenhoek, the proofs of whose experience, if I should again recite them, would fill both sides of the page. It is a constant truth that the vessel emanating from the heart, comes to an end in the cortex, and that by means of the cortex it is reborn a fibre, which returns to the heart or to some vein or artery thereof, from which, by a wonderful gyre, it again rises up to the cortex. *Thus, as the vein by means of the heart, is reborn an artery, so the vessel, by means of the cortex, is reborn a fibre.*

138. *As the vein, when reborn an artery, entirely changes its nature, so likewise does the vessel of the brain when reborn a fibre.* That the texture of the tunic of veins is different from that of the tunic of arteries, and also the nature of venous blood from that of arterial blood, is sufficiently evident from the teaching of angiology;—but here is not the place to explain this difference. We note merely that as the venous blood differs from the arterial blood, so the tunic of the vein differs from the tunic of the artery; for the one is so accommodated to the other that the tunic together with the blood constitutes the vessel. As regards the blood, it undergoes a change not only in the lungs but also in the heart; for the heart is a chemical organ preparing liquids for the composition of blood, (Trans. I., n. 453-457), for which end it also adjoins to itself the lungs, which are the appendages of the heart, as an aid. Hence also comes the transformation of the nature of the vessels. That it is form that makes things to be what they are found to be, see Transaction II., n. 244. As regards the cortex, it is not indeed the eye but the mind that, by comparison with the visible heart, comprehends that something similar can be predicated of the cortex, and also how far we may be allowed to carry the conjecture, (see Trans. II., n. 138).

139. *Hence, as the vein in respect to the artery is passive, and the artery in respect to the vein active, so the vessel in respect to the fibre, and the fibre to the vessel.* The vein can hardly be called passive in the sense that it possesses no activity whatever; for it is furnished with a muscular tunic, and it reacts so far as the blood which it pushes and propels toward the auricle of the heart acts (Trans. I., n. 190-198, 523); but the proximate cause of its action is due to the artery, (*ibid.*, *n.* 332.) Wherefore vein and artery proceed like two consorts of one marriage bed. So likewise the blood vessel of the brain, which, in itself, is quite active, but in respect to the fibre is passive. For all things in nature are relative, whence come measures, differences, degrees, and moments. *And because veins and arteries undergo this mutation by the mediation of the heart, so vessels and fibres undergo mutation by the mediation of the cortex.*

140. *But as soon as the artery of the body enters the threshold of the brain, that is, into the cranium, it frees itself from the empire of the heart and subjects itself to that of the brain; and hence it transcribes its active nature into a certain passive nature. By reason of this the arterial vessel of the brain, again become like a vein, is rendered passive in respect to the fibre, which is most highly active.* In Transaction II., n. 12-23, it was shown that as soon as the carotid artery touches the threshold of the cranium and becomes the internal carotid, it puts off its active and muscular tunic and superinduces a new tunic over that inmost one which it still retains. It was also shown that by angular flexures and repeated gyres, both in the bone itself and also below and above the clinoid processes, it frees itself from the empire of the heart to which it has hitherto been subject, and places itself under the will of the brain; likewise also the vertebral artery, to say nothing of the veins and sinuses of the dura mater. Again, it was shown that it is the cortical and cineritious substance which is expanded and constricted, or is that from which the brain animates (Trans. II., n. 132); and that when these substances are expanded, the whole mass of the brain with all its blood vessels and all its medulla is constricted, and vice versa, (*ibid.*, 141); and hence that the systole and diastole of the arteries, so called, of the brain, no longer depends on the heart, but on the brain, that is, on its cortical substance. By reason of this the vessels of the brain are passive or obsequious to the cortical substances and their fibres wherein the active force of the kingdom principally resides. With what art this arrangement is prepared, will be seen sketched out in the following chapter. For the present, it is a constant rule of nature that passive entities must be copulated with active in order that there may be a marriage, from which an offspring may be brought forth.

141. *The comparison which has been instituted, further teaches us, that as from the left ventricle of the heart a cavity is continued through the middle of the artery even to the last ends of its ramifications, so a little sinus or the minute chamber of the cortical spherule is continued through the middle of the fibre.* This is evident in the heart, for its left ventricle is extended into only one great artery, which is the parent of all the arteries of the body. As to a like ventricle, little sinus, or chamber in every single cortical substance, see Trans. II, n. 124-128.

142. *So that every medullary fibre of the brain and nerve fibre of the body is pervious and transpirable, or is gifted with a cavity, that is to say, is a little canal, not unlike the arterial canal.* It behoves us to dwell somewhat on these matters, for there are those who still deny the permeability of the fibres,—a denial which emanated from the peripatetic school. For the Philosopher,* in his work on PARTS OF ANIMALS, Book II. Ch. iv, has stated that the fibres are solid and earthly; and he thus seems to have so hardened these stems of our life and so stopped them up, that they could not be opened by Hippocrates, who asserts that there is nothing in the animal body which is not perspirable and transpirable.† That a cavity and a fluid runs through the fibre as through the artery, is indeed hardly perceived by the senses, but is quite evidently perceived by the mind. Those who judge of such things merely from the senses, are rebuked by Plato in his THEÆTETUS, in the following remarks: "There are uninitiated persons who esteem that nothing exists except what they have grasped with their hands; but efficiencies of actions and the generations and origins of things, in fine, whatsoever does not come under their eyes, this, least of all, do they believe to be in the class of things that exist. Truly, such persons are exceeding gross and are strangers to the muses," pages 155, 156 in my copy [Stephens' edition, p. 155]. Aristotle himself also speaks likewise, saying: "Ignorance of our superiority and of other matters springs from the fact that we are impelled to learn from the senses alone, nor do we abstract our thought; but, drawing our learning from it, because we suppose ourselves to have experience of all things, therefore we are accustomed to say that there is nothing that does not come under the senses." (*Divine Wisdom according, to the Egyptians,* Book XII, Ch. xx.) As to the cause of this ignorance, see in Trans. I, n. 623. But he who at this day, calls into question or gainsays the permeability of the fibres, he surely calls into question or gainsays experience enlightened by the microscope, that is to say, the evidence of sight. And therefore, that such a person may have faith in this truth, I am induced at this point to give a copious recital of the documents of experience.

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*By "the Philosopher" our author means Aristotle, whom he frequently designates in this way.

†These words are used in their root meanings,—*Perspirable* (passage through), meaning open to the passage of breath or spirit, as through a canal; and *Transpirable* (passage across), meaning open to the passage of the same elements, but through pores.

WILLIS treats of these matters in the following words: "The nerves themselves, as may be detected by means of the microscope, are furnished throughout their whole extent with pores and passages as with so many cavities thickly set in and mutually contiguous. Thus their syringe-like substance, like the Indian cane, is everywhere porous and pervious. Within these little spaces blandly spring forth animal spirits or corpuscles extremely subtle and of their own nature ever prone to motion; to which is adjoined an aqueous humor, itself consisting of extremely subtle parts, which serves both as a vehicle and also as a retainer. This nervous juice, derived from the cerebrum and cerebellum into the medullary appendix, is carried thence, by an ever bland flow, through the nerves into the whole nerve family, and irrigates its entire system. On the equable emanation of this fluid depends the expansion of the animal spirits throughout the whole system. And the substance of these spirits, yea, the hypostatic substance of the sensitive soul itself, is founded on the diffusion of this same humor." (n. 8.)

Bartholin. "The use of the nerves is, that, like canals, they shall convey the animal faculty received with the animal spirit from the brain, to the sensory parts, as to the eyes, ears, etc.; to the motory parts, as to the muscles; and to almost all parts that, in general, they may sensate and may recognize the things that bring them discomfort. The use of all the nerves is to carry animal spirit to all the parts, for the sake of sensation and motion, as is evident from their injury. For when obstructed in their beginning—if the obstruction be total, both sensation and motion perish and apoplexy results, or if it be on one side there is privation of sensation and motion on the other side; if they be cut, the motion of the side into which they were inserted is destroyed." (n. 12, 15.)

Vieussens. "The animal spirit runs through the nerve in many distinct and inexplicable ways, so that it accomplishes within it many distinct and inexplicable motions, for the diverse ratio whereof diverse thoughts are excited in the soul." [n. 17.]

Ridley. "I regard the fibre as being either an extension of some artery which by reason of its minuteness is rendered fit to contain only a liquid of this kind;* or a tubulous production of the same kind of artery corresponding in the proportion of its opening or pore to the figure and size of that fluid which nature intends it to receive. I hold that the fibre is incapable of taking up any fluid whatsoever, which has not first been reduced into the most minute particles, a process which comes under the name of Leptometry. I should take these ultimate vessels to be nothing else than the numerous still further capillary productions of the cortical vessels; so that the red vessels, or vessels of the blood, cause them to be gifted with a pore of such kind as renders them fit to receive only that most subtle, fine, and mild liquor, which, I take it, is the true medullary and nervous juice," etc. (n. 18.)

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*Called by Ridley, the "animal fluid."

MALPHIGI. "Whether these fibrous bodies are hollow, or at any rate, whether, when gathered into a fascicle, they transmit a peculiar juice through the resultant little pores and interstices into the nerves continued therefrom, is a matter that would require long investigation. The extremity of the fibres of which the brain is made up seems to be no light argument in favor of the existence of a separate humor in the brain and which is propagated therefrom into the nerves. For in its last little heads or roots the fibre is immersed in the cortex through which are ramified an immense abundance of blood vessels. From these circumstances we have reason for thinking that, in its inmost structure, the cortex or the cineritious substance derives into the fibres a fluid which is expelled from the vessels." (n. 21.) "That nerve fibres of this kind are to be classed as vessels, seems to be indicated by the well known fact, to wit, that when they are cut, a copious juice flows out, resembling the white of egg and coagulable by fire, as I have observed in a dissected nerve of the arm." (n. 20.) "Although we find in the cerebrum a net-like interweaving of fibres, still the humor of these filaments is not to be carried down by external adhesions, [nor is it attenuated and purified from foreign substances by means of the folds], as is the case in sponges; for the whole work of separating and purifying is perfected in the inmost structure of the cortical glands; and the humor which then issues from the glands, enters into the hollow and tubular fibres, and, by a continuous path, is sent off into the underlying parts for the performance of divers offices; as is the case in the tubular stems of vegetables, as intimated above," (*ibid.*),

LEEUWENHOEK, who was furnished with better glasses, frequently beheld the cavities themselves with still clearer sight and exhibited them to the view of others. "Not content with this observation, I endeavored, with what reason I could, to find out whether the little parts which I have spoken of as being very fine and somewhat longish, are interiorly pervious with hollow passages. At last, after some days, I distinctly recognized those passages or cavities with my own eyes, and this not once, but at least fifty times." (n. 26.) "In one respect I was unfortunate in this business, namely, in that I was unable to exhibit these cavities to the sight of others; for as soon as I moved them to my eyes for the purpose of examination, in less than a minute they suddenly collapsed by drying out, so that the remarkable sight wholly vanished beyond the possibility of being restored by any industry. Nor did I see merely the borders of these vessels,—vessels which seem to be gathered together to the number of some hundreds in order to make up a single nerve,—but in some of them, I also recognized the cavities, and this as distinctly as though we had perforated a piece of paper in a number of places with a very fine needle." (n. 27.) He presents a delineation of the cavities themselves in Fig. I., to the description of which figure the reader is referred; see, n. 29. "Nor can I add anything to what I have said above, (he continues), except that, because I was investigating the hollow passages of the vessels, I may have perceived them more clearly than before. [I showed through the microscope, the things described above to a certain man] and to my question, Did he not see the extremely minute vessels, and the foramina or openings of the vessels, he answered, Yes, I saw them at first sight. I then told him that what he had seen was a minute portion of those open little vessels of which the nerve is contextured." (n. 30.) "In the nerves of a calf, I found these passages not once only but many times,—a fact that gave me no little delight (n. 34)."

BOERHAAVE closes the array: "Whoever considers, 1. the nature of the cortex as set forth above, and the fact that the medullary fibrils arise from it in the most distinct way; 2. the similarity of this arrangement, with every other part of the body; 3. the vast abundance of the very finest, purest, and most mobile arterial blood, undespoiled of its subtlest part, that is driven hither with great force by the neighboring heart; 4. the exquisitely fine fluid always and everywhere to be found by sight, touch, and especially by the microscope, within the medullary substance when dissected,—a fluid which in diseases of the injured brain, is often greatly augmented; [5. the fact that the veins return to the heart the blood which has been brought to the venous sinuses by veins from the pia mater and the cortex of the cerebrum and cerebellum]; 6. the constant, ordered and proportioned increase, nourishment, propagation and return of these stamens from the first point of life to the last goal of life,—such a one must judge these fibres to be pervious little channels of the utmost fineness, that take up a humor, the most subtle of all in the human body, which, prepared and secreted in the wonderful fabric of the cortex and driven by force into these tubes, is collected from every point of the cortex into the medulla oblongata. If further, with attentive mind, one comprehends, 1. that the whole vascular medulla is expended on the constitution of nerve fibrils, yea, goes off into such fibrils by mere continuous extension; 2. that when the medulla of the cerebrum or cerebellum is compressed, cut, rotted, eaten away, every action accustomed to be done through the nerves arising therefrom, is at once abolished, even though the nerves continue unimpaired, and with membranes intact; 3. that the nerves, everywhere lax, pendulous, curved, retrogressive, oblique, yet execute motions and sensation with the utmost promptitude; 4. that, nevertheless, when compressed by constriction, the nerves, even though unimpaired, lose every faculty of motion and sensation in the parts that lie between the ligature and the last places to which those nerves are extended, their power between the point of ligature and the medulla of the cerebrum and cerebellum being unaffected, —he will most certainly conclude that the nerve fibrils assiduously receive the humor of the medulla, transmit it, and carry it down to every point of the whole body by the most distinct paths. Does it then seem wonderful to you that the eye cannot follow the presence and motion of this humor; that ligatures, wounds, punctures, suctions, air pumps, injections are of no avail to exhibit it before the eye; that by no skill can the cavities of the nerves be laid before the keenness of its vision? Truly, he who attempts such things with this intention, knows not the nature of these vessels and of the liquor itself. But he who, on this account, denies the existence, in these little vessels, of cavities that flee the sight and elude the skill, is surely ignorant of the rationale of our body in its origin, progress, operations, and excretions; and knows not the structure of insects, nor gives heed to the phenomena which so manifestly occur in plants. Therefore also gross is that error which recognizes the thickish lymph that trickles from the cut nerves of an ox's tail, as that humor, which we have just described." (n. 49-51, Trans. II., n. 95.)

See now the common agreement of the anatomists of our age with Hippocrates, as against ancient and modern philosophers who hold the contrary opinion.

143. *In addition to experience, reason also dictates the same thing; for without a fluid in the fibres nothing whatever in the animate body could derive and carry on its origin, progression, order, law, motor force, light, life and sensation; since a fibre without a fluid is a stem impotent of action.* But let us take up these points one by one. As regards *origin* and *progression;* this is evident from the thorough examinations that have been made of the beginnings of chicks in eggs and of embryos in wombs. For the fluid of the white and of the yolk is brought, by insensible pathways and pores and through intermediate vesicles, towards the carina,* and from this into the purest stamens, which, flowing forth from the tender little brains, enter upon the work of successively constructing the fabric of the viscera. Unless the fibre then emerging were determined according to the force of its fluid and the impetus of nature, or in the direction whither its soul leads, nothing of organic form, and no machine of such stupendous skill and genius, would ever be raised up. Compare the whole of Transaction I., chap. iii, on the Beginnings of the Chick in the Egg. [n. 241-315.] As regards *order* and *law;* for there would be no order and no law of order, unless there were a fluid capable of determination according to every force and mode of active nature. That fluids are the forces of nature, and that substances declare their quality by the mode of their forces, see

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*The first stem of the chick or fœtus.

Transaction II., n. 223. As regards ***motor force,*** as in muscles, glands, vessels; for when the fibre is compressed, or emptied, or distended with useless humors, or exhausted and worn out by old age, or infected with a wasting disease, it so undermines and demolishes the former strength of the muscles, that particular activities are turned into general, and there comes inability to exercise the several powers according to the decisions of the soul. As regards *life* and *sensation;* for if no such quantity of the animal fluid were reborn as, so to speak, is unborn; that is to say, if the fount of the vital humors begins to dry up; then, with the collapse of the fibres, the organs of sensation grow dull, and the very life of the body enters, as it were, into the shades of evening,—as is indicated by the single changes of state in ourselves. Suppose now the fibres to be without fluid; tell me how they exist, how they subsist, how they are nourished, how they act, suffer, live, and feel; or, tell me what animates the fibre, and what deprives it of animation. Is it not a fact that as far as the fibre is lacking in liquid, so far it loses its potency of action and sensation? not unlike as is the case in the umbilical and other vessels, which were formerly pervious to the blood, but becoming, in process of time, emptied of blood, are seen to take on the nature of ligaments and tendons. Let us therefore open up the fibres and consider it as established that they are little channels; for thus shall we have a pathway, open and clear, to the causes and principles of things in the animal kingdom; and we shall be assured that it is from the marriage of the fluid with its fibre, according to their established relation to each other, that we move, and sensate, and live. Add to this what is said in Transaction II., n. 165.

144. *Moreover, as the muscular surface of the heart is transmitted by continuity into the surface of the artery, so the surface of every part of the cortex is transmitted around its fibre.* There is no doubt but that the muscular fibre of the heart is continued into the great artery,* and from this into all the small arteries or capillaries, yea, even into the little veins, so that it returns to the heart; for otherwise, that is to say, in parts that are discontinuous, the systole and diastole of the heart and arteries, or of the whole arterial system, would cease. In addition to the muscular fibres, the superficial vessels also, otherwise called the coronary vessels, and, moreover, the cardiac nerves, are in part transmitted to the aorta. From the parallelism, a similar conclusion may be drawn in respect to the innumerable little hearts of the brain; that is to say, their lines, or rather the fibrous shades which weave their surface, pass by continuity into the fibre itself, and form its little tunic. See Trans. II., n. 114. The same is evident from the continuous action of the fibre from its beginning to its end; for there is no continuous action in things discontinuous.

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*The aorta.

145. *From the above considerations come the following conclusions: As in every point of the artery there is a likeness of the heart, so in every point of the fibre there is a likeness of the cortex.* By a likeness of the heart and cortex being in the arteries and fibres, I mean that they are as it were present in every point of them, although they themselves are not present individually, but only their force and power. It is not otherwise than is the case with a distant image in the eye, of which image only the likeness is present. In a similar way, the brain is said to be present in every point of the body. Without the presence of the heart in each point of the artery the latter would not beat almost simultaneously at the stroke of the heart; nor would the muscle act at the nod of the animus and at the first motion of the will; nor would the brain sensate, almost in an instant, the least differences of touches in the organs. And, therefore, in the brain, that is, in the cortex, is a likeness of the things that are represented in the external sensories; and in the muscles a likeness of the things that are perceived by the animus. Wherefore the formative force and substance, that is to say, the soul, is seen to have fashioned its body entirely after its own idea, or as a type of its own intuitions and representations; confer Trans. I., chap. iii. The cause and truth of this theorem is a consequence from the preceeding theorem of this chapter, namely, that the artery is a continued heart, and the fibre a production of the cortex, or its elongated appendix, etc., n. 133, 134, 135, 144; see also Trans. I., n. 173-179, 182-186; Trans. II., n. 202.

146. *For from the origin of their motion or touch, both actuate their enclosed little stream into the things that follow.* This is the continuous effect of the cause. For blood injected into the arteries flows to its exits, that is, into the veins, spontaneously, even without the force of the heart. Indeed, if you constrict, puncture, or pinch an artery, the moments of the friction or touch may be distinctly discerned in the succeeding branches; and hence by the pressure of a plectrum* or of the finger on living arteries, we are able to produce an artificial pulse different from that of the heart. The reason is, because the artery, from the origin of its motion or touch, actuates its fluent blood into the things that follow. Hence it is evident that the office of the heart is to inject the sanguineous wavelet into the aorta, and that the rest belongs to that artery itself and to the arteries, in whose every point there is a likeness of the heart. See Trans. I., n. 169-189. A similar thing obtains, but still more perfectly, in the fibres. Wherefore the forces of the muscles are excited not only by the determination of the cortex, but also by every touch and friction in the body. See Trans. I., n. 506, 507, 508, 561, 570, 574; Trans. II., n. 32, 33.

147. *As the artery, into whatsoever gyres it be flexed and turned, yet drives its fluid even to the extremities; so the fibre, in whatsoever manner it be flexed and turned.* As regards the arterioles, these are flexed and reflexed according to every form of the corpuscle which they irrigate,—as in the glandular vesicles, the muscular fibres, the sanguineous vessels, and elsewhere; for they are so easily drawn into gyres and spires that Leeuwenhoek has counted more than a hundred circuits in the space of a single finger nail. (Trans I., n. 125.) If it is the muscular tunic that pushes the blood on, it matters not to the artery what kind of curves it makes; but it would be otherwise if wave propelled wave. Fibres are borne still more perfectly into similar gyres, as is plain to be seen in the brain and the body. In the brain, the fibre, hatched from its cortex, pants through a thousand windings to its crossroads, its little stations, and its goals. Thus, in the case of that abundant fibre which runs from the cortical circuit and from both corpora striata, towards the medullary centre, it is twice or thrice reflected upon the roof of the larger ventricles, and frequently retraces its path, so as to find and embrace, in the corpus callosum, its companions of the other hemisphere; thence it curves back towards the base of the fornix, in order that, when almost returned, it may cast itself upon the thalami of the optic nerves. There are fibres which, like a network of threads, twist themselves into a thousand angular flexures before they seek the fascicles wherein they may proceed in a straight direction. The fibres of the cerebellum arise from the peduncle quite obliquely, towards the annular protuberance on the one side and underneath the testes* on the other where they so consociate and interweave themselves with the fibres of the cerebrum, here running to meet them, that they may, not unaptly, be compared with the spires and incisions in a stone mill-wheel (see the figures of Vieussens and Willis); and when both together have deeply immersed themselves, and in part have again emerged, they take a step backwards, and conjointly stretch their way to the medulla of the spine, or to some little nerve. The like is the case in the medulla of the spine, where in addition to perpetual circuits of fibres, there are also fibres that ascend along the neck in a straight line towards the great foramen of the occiput, and thence are flexed back towards the eighth pair† of the nerves of the head, and by this way return to the pharynx and larynx or to the neck. In the body in like manner; for the fibre creeps around artery, motor fibre, vesicle, follicle, glandular and gangliform corpuscles and grains, like ivy, especially the sensory fibre which, by sinuous plexuses and serpentine tortuosities, weaves papillary forms in the tongue, or other organic forms in the ear, the eye, and the cuticles. But why should I go through the fibres? such as those in the stomach, intestines, pancreas, spleen, liver, lungs, heart? In a word, it matters nothing whether the fibres be borne backwards or forwards,—provided only they be bent whither use commands; for, despite all, their fluid, emitted from the cortex, passing through innumerable labyrinthine windings, nowhere set back, that is, nowhere delayed by what it meets, hastens on, quicker than the flash of an eye, or than the will, to its ultimate organic goals, sensory or motory. Therefore since the fluid runs through the fibre and modifies it; and since, when the fluid acts, the tunic reacts in the most perfect manner, and vice versa; and since in every single point there is a likeness of the cortex; it follows that this fluid runs through its canal spontaneously, howsoever the latter be flexed and reflexed. Indeed it will be demonstrated that the circular or spiral form of fluxion is more suitable to the nature of fibres than the rectilinear, into which latter the fibre is not borne but forced, as when it is bound up in a nerve.

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*A Plectrum is the stick used by the ancients to strike the chords of a musical instrument; our author seems to refer to a stick or other similar instrument, perhaps technically called a "plectrum," used to assist in the compression of blood vessels.

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*The reference is to the testes of the brain; seen n. 83, note.

†The Par Vagum; see note to n. 117, above.

148. *As the artery drives its blood forward by a mode of undulation, whence arises the pulse; so the fibre drives its fluent spirit by a species of superior undulation, or by modification.* That the circulation of the blood is carried on by a successive promotion of the undulation within an imperceptible moment of time, whence arises in every single part of the permeated vessels that sensible elevation called the pulse, see Trans. I., n. 166-170, 179; and that this little wave, having received its first impulse from the heart, is afterwards promoted by the whole arterial system, *ibid.*, n. 173; that this is done still more rapidly in the fibres, *ibid.*, n. 176. Modification belongs principally to the auras and also to the animal fluids; and it corresponds to the undulation seen on the surface of water. For sound comes to the ear by modification of the air, and an image [to the eye] by the modified ether. Thus modification signifies a mode of the transmission of a sound or image from one distance to another. Such modification never exists without an origin or a principle of motion. But the doctrine of modifications is of such great extent and excellence that it easily holds the first place in physics; for the quality of nature, yea, and of substance, declares itself by modification. That the animal fluid emulates the modifications of the atmosphere, see Trans. II., n. 269, 290, 291. But to proceed: It is evident from the fabric of the arteries and that of the fibres which is compared to it, that both arteries and fibres are constructed after every form of the undulations and modifications of nature.

149. *Thus every wave expelled from the first starting point of motion is present, not actually but potentially, in its latest goals.* For such is the nature of modification; in such way is the solar ray carried to the earth, an image to the eye, sound to the ear, a wave to the shore,—the wave being not the same as that which was first expelled but continuous therewith.

150. *As the blood running through the arteries is borne along in a steady stream and with increased celerity; so the fluid through its fibres.* Concerning the arteries, see Trans. I., n. 174, 175, 176, 179. The same also follows from the fact that there is a likeness of the heart and cortex in every single point of the artery and fibre, and that there is a tunic which simultaneously actuates the little stream. If neither the tunic nor the inflexions of the vessel cause any delay (n. 147), it necessarily follows that the celerity of the motion increases, and not the reverse. If the mere force of the heart actuated the fluid, then the celerity would be the rather diminished; and therefore many of the learned have fallen into this opinion, although all effects and phenomena dictate the contrary. This undulatory transmission of the blood may be compared with the rise or fall of bodies from one region into another that is either lighter or heavier; that is to say, such bodies in their ascent or descent continually increase the degrees of their celerity in a duplicate ratio.

151. *As the tunic of the artery is formed to the nature of its blood; so the tunicle, or most delicate surface of the* *fibre is formed to the nature of its fluid.* That the tunic of the artery is most exactly accommodated to the nature or the force and mode of action of its artery, see Trans. I., n. 134, 135; and indeed so exactly that, given the blood or its nature, we may conclude as to the quality of the tunic, and, given the tunic, as to the quality of the blood; for the fluid constructs its own tunic, as is evident from the first stamens of the embryo and chick. So also the fibre in respect to its fluid. But the nature of the fibre's tunic will come to be demonstrated below; and, therefore, I defer for the present any further treatment of the conformity and parallelism existing between the fibre and the artery. There is one thing, however, which, I think, should not be passed by in the present treatment, namely, that the tunicles of the fibres are of such great fineness, that they distinctly comprehend, carry down, and sensate the forces of purer nature, such as the modifications of the most subtle ether, or the distinctions between the lightest touches and the forms, harmonies, and disharmonies arising therefrom. If the tunicle on which the modifying forces impinge were not most exactly accommodated to the nature of its fluid, the organ woven of the fibrils would never actuate any sense, nor would an image exactly similar to that which is, as it were, present in the external sensory, be at the same moment represented in the cerebrum. Wherefore as soon as the apt formation of either [the fibre or its tunicle] begins to be destroyed or obliterated, then distinctions of modes and the differences between things begin to be confused, that is, sensations begin to grow dull. The nature of the change undergone by arterial and venous vessels when, later on, they are permeated by a fluid of another kind, is clear from the umbilical vessels, the hepatic tube,[*] the arterial canal,[†] the muscular tendon, and from other more minute vessels in the skin, the dura mater and elsewhere,—all of which then simulate filaments, cords, funicles, and muscular strings; in a word, canals of another origin, disposition and denomination.

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[*] Our author, perhaps, refers to the ductus venosus, a vessel in the fœtal circulation that carries the placental (arterial) blood from the portal vein to the inferior vena cave. The ductus venosus becomes impervious three or four days after birth.

[†] The ductus arteriosus,—a short vessel in the fœtal circulation that carries the venous blood from the pulmonary artery to the aorta. After birth it becomes closed, and is called the arterial ligament.

152. *Thus the tunic and its enclosed fluid constitute one vessel and act as a single cause.* The containant and the contained taken together are what is here called a bloodvessel or fibre; for a vessel without blood and a fibre without its contents of uttermost fluidity, is a mere membrane; while the blood without a tunic is a mere undetermined liquor. It is the continuous or coherent part of the artery and fibre, that is to say, it is the tunic, that is the highway for the determinations of the fluid from the interiors of the kingdom to its exteriors, and vice versa.

153. *Hence, as the circulation of the blood is carried on through the arteries by the active and reactive force of their muscular tunic; so the circulation of the purer fluid through the fibres by the active and reactive force of the enclosing tunicle.* That the tunic acts upon the blood and the blood upon the tunic, or, that the one is passive when the other is active, may be seen amply confirmed in Trans. I., n. 182-186. The whole of medical science lies in the restoration to the blood of its action, and to the tunic of its reaction, that is, of its natural tension. So also in the fibres, to which we can be led by induction from the arteries by a mode of elevation to a superior power, as in analytical calculus. But for a deeper understanding of the subject, the fabric of the tunic itself must be expounded.

154. *As the artery, distended with its blood, is stretched lengthwise, and at the same time breadthwise; so the fibre traversed by its fluid.* That the artery of the body is stretched out when dilated, see Trans. I., n. 228, 229. But it is different with the artery of the cerebrum, which changes its natural disposition into a disposition mediate between the venous and arterial, *ibid.*, n. 218. But to proceed: That impletion expands the artery at the same time that it stretches it, is clear from the nerve when taken out and dried; for it then contracts and shortens. Indeed a fibre, when cut, springs back, as it were, to itself, and is twisted up; confer Trans. I., chap. vii, [n. 460-578] on the cardiac nerves, and Trans. II., n. 172-175. But that, in these respects, the fibre itself induces a similar nature on the arteries of the brain or palace of the body, that is to say, that it is shortened when filled, will be demonstrated below.

155. *As the artery flows from the heart into the motor fibres of the muscles; so the fibre flows from its cortex into the same motor fibres, but at unlike moments; whence arises action and reaction, and, from this, alternate and reciprocal motions.* That the proximate efficient cause of muscular motion is the fluid in the fibres and the blood in the arteries, which two mutually and alternately react on each other, see Trans. I., n. 504, 511. Moreover, every tyro knows that into each muscular fibre flows a fibre from the cerebrum, using the term in a broad sense, and an artery from the heart; and also that when the artery or fibre is injured, compressed, emptied, or cut off, the muscular action ceases; and that the animation of the cerebrum coincides with the motion of the heart, not in adults, but in the embryo, Trans. I., chap. iii, [n. 241-315]. For the rest, see our Transaction on the Muscles.*

156. *As in the arteries resides strength; so in the fibres resides the force of forces and the life of the body.* Concerning the arteries, see Trans. I., n. 231-233. But that in the fibres resides an active force, or, in the simple fibres a force of forces,

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*No Transaction on the Muscles was ever published by Swedenborg. But among his manuscripts are two which deal with this subject. The first, consisting of 22 quarto pages, is entitled "8. On the Muscles in General," and consists of extracts from Boerhaave, Willis, Vieussens, and Winslow (3 *Documents.* 866). The other, which consists of 13 folio pages, is clearly Swedenborg's Induction. It deals with the muscles of the face; the affections of the animus as effigied in the countenance; and the muscles of the neck and abdomen. (3 *Doc.* 942, VI. *Phot: MSS.* 13 *seq.*) These two manuscripts are probably the draft of a portion of the proposed treatise on the Muscles, which was to have formed one of the "Transactions" of the ECONOMY OF THE ANIMAL KINGDOM.

is sufficiently comprehended from their origin, field of action, and effect. *The origin* is in the brains, whence, as from a common fount, flow forth all the forces or actions of the muscles; and this by way of the fibres, which are so many highways of determinations. *The field* or extension of *action* is into the whole body; for where there is no fibre, there is no active force and sensation, but instead, something dissociated from the sensitive and voluntary life of the brain. For superiors flow into inferiors, and vice versa, according to the mode in which the substances are formed, and in which, by connection, they communicate with each other. Trans. I., n. 622. *The effects* are sensations and actions, or are all those phenomena of the kingdom produced by the fibres together with the arteries; for, in the whole system, there is nothing but fibre and vessel, the determinations of these being the forms that constitute the entire animal machine. But to proceed: In order for the existence of strength there must be efficient forces of strength. Hence, if there be strength in the arteries, the fibre must be the efficient or producing force. This is apparent from the fact that the fibre inflows into the tunic of the artery, and the fluid of the fibre into its blood. Therefore, in familiar speech, we are accustomed to attribute the force and strength of the body to the nerves. From these considerations it is sufficiently evident why the arteries only, and not, like elsewhere, their accompanying veins, ascend from the kingdom of the body into its palace or cerebrum, and there, by means of the cortex, transcribe their life, now at the end of its course, into the fibres; namely, in order that strength may be added to the brains, force to the imagination and hence to the genius, and a faculty capable of determination to the will.

157. *In a word, as the artery is continually striving to constrict itself, or to contract to its least diameter; so also the fibre.* That the artery loves to stay and rest in the least diameter of its contraction, see Trans. I., n. 178, and the experiments there adduced. For experiment has shown that the muscular tunic of every artery presses upon the enclosed blood, whence arises a general equilibrium of the pressure of the arteries; on which subject, see Trans. I., n.

178, *seq.;* and a wave sent from the heart into the artery, wheresoever it be, is urged to its exits, that is, into the veins. Nor can it be doubted that the tunicle of the fibre also endeavors after the same thing. For when hurt by the least friction, it straightway wrinkles up, contracts, and quivers; and when cut, it betakes itself to its spire, twists up, and closes. *But the fluid, emitted and injected alternately by the heart and the cortex, holds both expanses.*

158. *Thus the artery and fibre are continually balanced between a state of the highest constriction and of the highest expansion, that is, between death and life.* Constriction is the death, and expansion the life, of both artery and fibre. For in the dead, they are emptied, closed, contracted. So likewise in fear, which is a likeness and simulation of death, since death then stalks before the eyes; for the blood then rushes headlong from the arteries into the veins; hence the muscles loosen, the joints fail, and the mind is arrested as though half extinct; all of which effects result from the constriction of the artery and fibre, or from the cessation of circulation. In the midst of these dangers life does not return to the body unless both vessels be again raised up, and the circulation renewed; for, in the animate body, which lives by motion and is moved by life, there is nothing excepting the artery and the fibre. Therefore we die by nature, because, of itself, the artery is continually striving to constrict itself, or to contract to its least diameter, n. 157; but we do not thus live by nature, because the artery and fibre are forced to expansion contrary to their own nature, and this by means of life or the soul, which is the superior force. Or, what comes to the same thing, in that we are body and matter, we die; but in that we are soul, we live; for nature regarded in herself is dead, and merely serves life as an instrumental cause, Trans. II., n. 231-237. And hence, because the artery and fibre are alternately compressed and expanded, it follows that there is in us a continual combat between death and life; or, that death, by incessant assaults challenges life, and life by incessant victories subdues death, until finally, in that we are natural, we lie down in death, but, in that we are spiritual, we are restored to life. Thus, when we have paid the debts of nature, we conquer even when conquered.

159. *Therefore, by the animations of the brain, the respirations of the lungs, the systoles and diastoles of the heart, and the circulations thence arising, there is a continual renewal of life.* And therefore, as soon as the motion of the brain, lungs or heart ceases, the circulation of the fluid in the fibres and of the blood in the vessels also ceases; and when the circulation ceases, the life of the body ceases. This life, which is believed to be continuous, is punctuated with perpetual threats, and, as it were, alternate times of death; for every systole is the threat of death, and every diastole the announcement of life. These changes or moments are parts of the general life; and hence it is evident what lot awaits our life; namely, that our waning years must needs continually sink down by a declining path; or, that the parts involve their general in the same fortunes to which themselves are subject. But to resume: Since our life is interrupted with so infinite a number of deaths, it cannot but be clear that that deserves to be called death rather than life, which is the cause of the darkness of our mind; a mind which then only lives when it is raised up from nature,—that is, from the world and its blandishments, and the body and its allurements, all of which are of themselves dead,—to God, who is the one only life and the sum of life.

160. *But between the arteries and the fibres there is a difference of velocity and perfection, or of moments and degrees, according to the laws of the doctrine of order.* The tenets and laws of the doctrine of order may be seen in Trans. I., chapter viii., [n. 633-652], especially n. 648. For there is such a co-established harmony of all things in the same series, that they mutually correspond to each other, with a difference merely of perfection according to degrees. Wherefore inferiors regard superiors as their analogues and eminences; and so also the arteries, the fibres, (*ibid.*, n. 626). The more simple substances also are prior and posterior, remote and proximate, and, among themselves, like efficient causes and effects. Those which are prior are also more universal, and in their every quality, more perfect than those which are posterior, (*ibid.*, n. 613-617). And, such as are the substances, such also are their essences, attributes, accidents, and qualities, or all their adjuncts, (*ibid.*, n. 618-621).

161. *The ratio of the conformity of the artery and the fibre, is gathered from the conformity of the fluids contained in them; for through the artery runs the red blood with its accompanying serum, and through the fibre the purer essence of the blood, or the animal fluid; which two mutually correspond to each other.* On the correspondence of these animal fluids, see the explanation in Trans. II., n. 222, and the passages cited at the end thereof. In the meantime, if the fluids mutually correspond to each other; and if the tunics are so conformed to the nature of their fluid that the two together constitute one vessel and act as one cause, (*sup.*, n. 151, 152), it follows that it is from this circumstance we are to seek the ratio of conformity and analogy.

162. *But they differ in the following particulars, namely: that to all the arteries is prefixed one great heart; but to each and every fibre so many little hearts.* This is confirmed by microscopical examination; for from every single gland of the cortex a fibre is put forth, so that there are as many fibres as there are cortical parts. This is the reason why there is so great a luxuriance of the cortical parts, that they may be numbered by myriads. *Also that the arteries are continually ramified, but not so the fibres.* For fibres are girt about with a tunic of the most simple nature, or with a most delicate sheath, on which account they no longer suffer themselves to be split up into branches,—it being only nerves, or fascicles of fibres that are thus split up. This also is the reason why so minute a heart or head is set over the fibres, while over the arteries of the body is set a great heart, in order, namely, that it may be equal and adequate to every ramification, that is, to the sanguineous system.

163. *Moreover, that in its extremity, the artery goes off into a vein; but not in the same way, the fibre.* That the artery finally passes over into the vein, is evident; it is not so evident, however, that the fibre does likewise. But from the comparison instituted above between the nature of the vessel and that of the fibre, we conclude that the vessel flowing into the spherule of the cortex, is a vein relatively to the fibre; for as the vein flows into the heart, so this vessel flows into the cortex, wherein it is united with the fibre in a manner hardly different from that in which the vein is united with the artery in the heart. And therefore our statement, that the fibre does not pass into a vein in the same manner as the artery. How it does pass, here is not the place to say; still I might declare the matter in a few words and obscurely: A deep examination into the determination of the fibre makes it evident that the fibre constructs the arteries, and that the arterial thread thus constructed is infinitely expanded in the body into a glandular form,—a form not unlike the cortical,—a vesicle or a spherule, from whence is put forth a little duct or corporeal fibre that returns to the cortex by way of the inmost tunic of the artery. In this way the fibre is seen to go off into a kind of corresponding vein. But of these matters we shall treat below, when we take up the corporeal fibre. *And finally, that the circulation of the blood through the arteries is distinguished by the pulse; but not so the circulation of the fluid through the fibres.* And this because of the reasons adduced above, n. 148, 150, 160; that is to say, because of the imperceptible moments of velocity obtaining in the fibres.

164. *From this comparison we may be allowed to judge concerning the use of the vessel and the use of the fibre in the brains; that is to say, because the vessel, in respect to the fibre, is of a passive nature, and the fibre, in respect to the vessel, is active,* (see above, n. 139-140), *that therefore every compound part of the cerebrum, small and large, is made up of fibres, that is, of active parts, and at the same time of vessels, that is, of reactive or passive parts.* These two principles of nature, the one active, and the other passive, must be within every single compound; for what would active force do and effect, and whither would it be determined, if there were not something to resist and suffer? On the other hand, what would the passive and inert be, if not an instrument which might be used, and upon which, as upon its object, active force might spend itself? Active forces, therefore, taken by themselves, and passive forces taken by themselves, produce nothing whatever, nor do they mutually coalesce. Therefore, wherever there is a compound, there must be within it those two principles, which are here represented substantially by fibres and vessels. That we may know what passive force is, or the force of inertia,—this is evident from the definition given in Wolff's Cosmology, namely, that it is the principle of resistance to motion in bodies, § 130; and that the force of inertia resists every mutation, § 132; for the definition of active, primitive, living or derivative, and motive force, consult the same author. By passive here is not meant that which is wholly inert, or which, of itself, becomes absolutely quiescent; but that which is relatively less active, and which to other and more passive entities, may be quite active; as, for instance, the veins of the body in respect to their arteries, and, in the present case, the vessels, in respect to their fibres; or, to use an analogous example, as a consort in respect to her husband. For reaction is likewise action, although they are opposed. That no compound or offspring which is a substance by itself exists without these two natures rightly consociated with each other, is clearly enough evident from the members and parts of the animal body, such as the brain, heart, lungs, stomach, muscles, glands, arteries.

165. *And thus that the vessels constitute the surface of the compound part, while the fibres constitute its body.* For these forces are usually so consociated, that the active reside in the center, and the passive, resistant, reactive, obsequious, or more or less inert, are rejected to the peripheries. Indeed, very frequently they are in such order of succession, that the activity of the center gradually decreases towards the peripheries. But let us be enlightened by examples: The cerebrum stores up interiorly in its hemispheres, its most active parts or its very forces substantiated, if I may so speak; that is to say, the cortical glands and the fibres. These it covers over and encloses first with a delicate mater [the pia mater], then with a hard [the dura mater], and finally with the inactive cranium. Nor can it be doubted but that each single part of the cortex, and each plexus, and also each fascicle of fibres, and each nerve, is coherent in the same manner, for each one of them is girt about with its own membranes. In the nerves, fibres constitute the axis and vessels the membrane. So also in the heart, where the veins are rejected to the surface; that the coronary vessels are all veins, see Trans. I., n. 421, 422, 459. In the arteries and veins, likewise, in which, as was shown above [n. 139, 140, 153], there is action and reaction, or an active force and a passive. So also in the lungs, which are coerced by the pleura and ribs; and, moreover, in the stomach, pancreas, liver, spleen, and the rest of the viscera; and still more plainly in the glands and muscles, for these are enfolded in a manifold series of membranes.

166. *Hence arises a natural tempering and a limited extension of forces; and a series is born, wherein the centre is regarded by every point of the surface, and the surface by the centre,—a series which limits the inseated forces to within a determined sphere of activity, and sustains, coerces, weighs and governs them.* That this is not mere reasoning or vain conjecture, is confirmed by experience. For in the cerebrum the vessels everywhere form a membrane, according to the testimony of those clear sighted anatomists, Malpighi and Leeuwenhoek. The same is also plainly visible in the fascicles of fibres that emerge from the medullary stem; for interiorly these fibres are bound together, and exteriorly they are girt about by the pia mater and afterwards by the dura mater. It is likewise visible in the arteries, and also in the fibres; these being interiorly permeated by fluids, which are the forces of nature in form, and exteriorly coerced by tunics.

167. *In this way, vessels are present everywhere in the medulla of the cerebrum; from which it follows that wherever a fibre or active force is lacking or begins to be lacking, there the vessels raise up a new cortex or cineritious substance (from which spring forth new fibres or new forces), according to every ratio of composition in the beginnings of the nerves, and according to the use in their extremities.* This now, is the reason why active substances, such as the cortical substances and the fibres, are so abundant in the brains that they must be numbered by the myriad; and likewise the vessels, which are infinitely ramified; and also why the cineritious parts abound, not only in the circuit of the cerebrum, but also in its interior medulla and in the corpora striata. That these cineritious parts are raised up anew, branch out and are perfected, yea, that they die away and are abolished, is testified to by a thorough examination of the brains of the dead. In puppies, according to Willis, these substances hardly as yet appear; and in brains worn out, and also in those which have been weakened by venery they are seen to disappear. But to continue: The very necessity of the offices and use in the extremes demands that the cerebrum here hatch out new forces and there obliterate the old as useless. But to describe all these changes in animal kingdoms is to descend from universals to special and particular points, and to spread out from anatomy to the pathological phenomena of the body and animus.

CHAPTER IX.

VESSELS OF A MIDDLE NATURE, THEIR ORIGIN, NATURE AND FUNCTION IN THE BRAIN; AND CORPOREAL FIBRES.

167a. *Vessels of a middle nature are those stamens of which the tunics of the cerebral arteries consist, and of which the pia mater is contextured. For when released from their membranes, they are of the utmost delicacy, and appear like fibres. But because they are not fibres, nor vessels such as we have hitherto treated of, but are of another origin, nature and function, therefore we call them vessels emulous of the fibre. These vascular, or, if you prefer the word fibrous stamens, are those stamens taken from the tunics of the arteries, which produce, restore, and irrigate the cortical glands, that is, the whole cineritious substance of the cerebrum, cerebellum and both medullas. For the cortical glands hang from the sides and tunic of their parent arteries, from which they frondesce, no otherwise than as grapes and berries around the tender* *stems and twigs of a tree; and they spring forth and become fruit, not from the woody and medullary portion, but from the cortical portion, or from the inner bark.*

When the cortical glands have been thus germinated, purest stamens of a like nature, drawn from the pia mater, superadd themselves, forming and weaving the most tender meninx of the cortical glands. For thus the universal enters into and determines every singular, and a common animus rules in the least particulars of the cerebrum; like as in other compounds, such as the glands, ganglia, nerves and muscles of the body, wherein the engirding membrane gives off shoots, which invest the enclosed parts and at the same time connect them. These stamens or vessels emulous of the fibres, rush forth, fascicle-wise, from the tunic of one artery and inflow into the tunic of another or neighboring artery; and this so compactly that they form a species of membrane wherewith they connect artery with artery and join them together. To these stamens, fibrils detached from the interior layer of the pia mater, seem to add themselves at a perpendicular, and together with the transverse fibres of the tunics, to weave an entire membranous web.

In this way, these vessels emulous of the fibre, firmly hold, not only the larger vessels and their offshoots, but also the cortical glands which depend on the vessels, and the fibres which depend on their glands, in a suitable situation, distance, connection, order, law, form, mutual regard and determination, and in the stream of the general and particular motion; and this, howsoever the cerebrum is expanded or constricted, howsoever it bears itself, is tumultous, agitated or smitten; that is to say, whatsoever the action of the sense, the animus, and the will. And thus preserve, whole and perpetual, the permeability, circulation, and life of the single parts.

Fascicles of such fibres, stretched out between the tunics of the arteries on both sides, emulate the motor fibres of the muscles of the body. And like binding and combining cords, they not only connect the arteries in respect to their tunics, but also so extrinsically dispose them, that they perform and *keep up their systole and diastole in the most obsequious manner, according to the every nod of the cerebrum.*

And, at the same time, they hold their alternate expansions and constrictions within stated limits, (not unlike the chordæ Willisianæ in the interior of the falciform sinus), and govern them, and, as it were, poise them on the beam of a pair of scales; for they react and draw back just so far as the forces of the cerebrum and the blood enclosed in the arteries acts and produces tension. Hence arises action and reaction, and as many restorations of the state as there are changes. The fibres thus colligating the cerebral blood vessels also provide that the vascular or fibrous stamens of which the arterial tunics are woven, be never devoid of their due abundance of perfluent humor. For, by means of these fibres, any portion of the fluid found in the tunic of one vessel, or in the stamen of one tunic, is communicated to all the others, wheresoever they may carry on their action. Thus there is not the smallest hair-like vessel the filament of whose tunic cannot demand from the public what it needs, and call that common property, yea, proper to itself and its very own, which the neighboring and even the more remote vessels possess and carry. This is of the greatest importance to the cortical glands which, originating from these little stamens, draw out and suck from them their essence and purer juices.

Moreover these vessels emulous of the fibres forming a species of continuous membrane between the tunics of the cerebral arteries, are like uninterrupted paths and little bridges flung across, whereby there is a connection and continuation of the one with the other. Hence it follows that the sensations, modes and degrees of each single organ, as soon as they are immersed in the medullary lake of the cerebrum, spread themselves out to every point of the vessel, meninx, cortex, and fibre; and thus present to the most simple little brains, that is, to the internal sensoriola or the cortical spherules, a representation of the image that has been impressed on the external organ, and by the nerves, has been poured forth into the medullary field of the cerebrum, and this in a type and idea similar to that in which it had been received.

168. *Vessels of a middle nature are those stamens of which the tunics of the cerebral arteries consist, and of which the pia mater is contextured.* The cerebral vessels of which we have just treated, however much, after entering the cerebrum, they may have transcribed their arterial nature into a nature similar to the venous, that is, into a passive nature (n. 138-140), I yet wish, in the following pages, to call arteries, and this for the reason that they are continuations of the arteries of the body; and, in anatomical matters, it is very desirable that there be no rash departure from a usage of speech, or from a term that has been once introduced and received, however unsuitable the term may be. That these stamens are not vessels, is evident from the fact that they constitute and contexture tunics which are extended continuously with the vessels and their branches; for a branch, pierced by a cavity, cannot finally become a stamen, unless it be reflected back over an artery. Nor are the stamens fibres, since fibres spring forth from their cortical glands, from which they are drawn out as appendices. These stamens of the tunics are closely cognate and homogeneous with the stamens of the pia mater; and that the latter are of a similar origin and nature, will come to be demonstrated below in the Transaction on the Pia Mater.*

169. *For when released from their membranes, they are of the utmost delicacy, and appear like fibres.* On this account, Leeuwenhoek, who was the first discoverer of these vessels, styles them fibrils of the cerebrum. How ineffable is their abundance and fineness is frequently mentioned and reckoned up by this author in his observations. And because they intermingle with genuine fibres and genuine vessels, they cannot readily be distinguished from either. Nevertheless, we may

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*A Transaction on the Pia Mater was intended by Swedenborg as part of his ECONOMY OF THE ANIMAL KINGDOM series; but no Transaction or chapter on this subject is contained in the present work. In a large manuscript on the Brain, however, one chapter is devoted to the pia mater; and, in addition, Swedenborg wrote two shorter treatments of the same subject, both of which are included in the English translation of the work on THE BRAIN. To this work, therefore, n. 410-419 *h*, and particularly, n. 419 *e*, the reader is referred.

still follow them up and discern them as disclosed by the eye of the mind.

170. *But because they are not fibres, nor vessels such as we have hitherto treated of, but are of another origin, nature and function, therefore we call them vessels emulous of the fibre.* Of their origin, nature, and function, we shall treat in what follows. But before we proceed, it is necessary to acquire a clear idea concerning vessels of this nature from Fig. 9, and the description thereof, n. 37, 129; otherwise, I must needs speak things obscure and but little understood; not unlike those who talk Greek to persons who do not understand Greek, and yet the same matters are set forth clearly enough in that language,—but to those who understand it.

171. *These vascular, or if you prefer the word, fibrous stamens, are those stamens, taken from the tunics of the arteries, which produce, restore, and irrigate the cortical glands, that is, the whole cineritious substance of the cerebrum, cerebellum and both medullas.* From Transaction II., in the chapter on the Cineritious Substance of the Brain [n. 69-207], it is, I think, sufficiently well established that this substance is the principal substance of the animal kingdom. There can be no doubt but that the cortical substance is so connected with the vessels of the cerebrum that one might naturally believe its glands to arise from these vessels,—as, indeed, is asserted by the most experienced anatomical investigators, such as Malpighi [n. 21] and others. One point, however, must be called into question, namely, whether or not the cortical glands are terminations of the arteries. That is to say, Do the arterioles in their extremities end in a gland, wherefrom is born a continuation which is a fibre? Or does the arterial vessel, while continuing on its path, produce such offspring from its tunic, and yet itself go on further as an artery? The analogous example of plants or fruits gives us reason to conclude, that, probably, the above mentioned glands do not frondesce from the arterioles direct, but that they do this from the tunic or membranous part of the vessel. In plants and trees, or in the vegetable kingdom, it is quite clear

that the first germs or buds of fruits blossom, not from the wood, but from the soft bark of the twig, as is plainly seen in grapes, berries, mulberries, strawberries, cornel cherries, and other vegetable offspring. The same is still further confirmed in the case of broken and fallen trees, which still give forth vernal flowers and fruits, even when only the bark remains. Not unlike these, may be the fruits in the animal kingdom, that is to say, the cortical spherules which are the last offspring of the sanguineous vessels and the first of the fibres. This is taught by comparison; for in these and similar matters we may be allowed to compare the animal kingdom with the vegetable. The shoots or branches of trees correspond to the arteries of the cerebrum; the bark of the shoots or branches to the tunics of the arteries; and the fruit or berry to the cortical substance itself, which is the last production of the artery. Thus from the analogous example of plants, we may be allowed the deduction that the cortical substances, or the offspring fruit of the arteries, do not spring from the vessels direct, but from their tunics. The same may be confirmed also from a comparison of the heart with the cortical substances which are so many simpler and more perfect little hearts, n. 135. For the heart of the body does indeed depend on its vena cavas, the ascending and descending; but both these veins swell out and coalesce into one great sinus, called the right auricle; from this auricle, or swollen venous sinus, the heart itself comes forth, like an appendix. From this comparison it follows that the vessel, when it goes off into a cortical gland, likewise begins to swell, and that it draws from the matter of its tunic a substance, which constitutes the very body of the cortical gland, a substance, however, that is more simple and perfect in the cortex than in the heart of the body; and hence that the tunic, or the matter of the tunic, goes off into the matter of the cortex, in a manner scarcely unlike to that in which the muscular substance of both vena cavas and of the auricle goes off into the body of the heart. Add to this the confirmation arising from the fact that the arterial vessel of the cerebrum is never seen terminating in a cortical gland, but as continuing its way, and, in the meantime, giving rise to many such glands at its sides, like the little branches of a tree give rise to the flowers of fruits. The same thing, moreover, is further confirmed by the rules of the doctrine of Order and Degrees;* for ascent to a superior degree and potency is made, not by ramification, but by means of vessels of a middle nature which are already elevated to a higher potency. But I confess, that here we are not able to bring forward ocular experience as a sign of confirmation. For, since even the ramifications of the arteries cannot be followed by the microscope, how then shall the stamens springing from the arterial tunics? Still we may be allowed to await the favorable assent of experience, and in the meantime, it behoves me to formulate reasons from analogy and comparison; which, however, although they persuade us, yet cannot but appear under the garb of conjecture. But in the meantime, from these as principles, we have drawn a series of consequences, on which, if they entirely agree with all the proofs of experience, I ought certainly to proceed, being sure of the truth of the principles. For if causes are confirmed by all the effects, and this without exception, I know not but that the cause should stand firm and entire, and be the verimost cause to be predicated of the effects. Therefore comes the sequence: *For the cortical glands hang from the sides and tunic of their parent arteries, from which they frondesce, no otherwise than as grapes and berries around the tender stems and twigs of a tree; and they spring forth and become fruit, not from the woody and medullary portion, but from the cortical portion, or from the inner bark.*

172. *When the cortical glands have been thus germinated, purest stamens of a like nature, drawn from the pia mater, superadd themselves, forming and weaving the most tender meninx of the cortical glands.* That the cortical glands are girt about with a most delicate meninx, there is no room for doubt; for, in lesser type, they are not only little glands and hearts, but also little brains, see Trans. II., n. 191-196. Add to this, that whatever enjoys any active force must also be furnished with a limit or tunic which shall terminate the forces;

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*See n. 137, note.

otherwise it would not be confined. And that this most delicate meninx, or finest pia mater, which overlays each single cortical gland, is derived by continuity from the common membrane of the cerebrum called the pia mater, we are persuaded both *a priori* and *a posteriori*. *A priori:* Because thus, and in no other way is there a connection of all the particulars with each other mutually, and with the general. *A posteriori:* Because the meninx insinuates itself in the single folds and winding fissures of the cerebrum, and covers each one as it covers the cerebrum itself. This is confirmed by such clear-sighted investigators of the brain as Pacchioni, Willis, Leeuwenhoek, Ruysch, and others. It is equally confirmed by the nerves also, which are the particular productions and appendices of the medullary portion of the cerebrum and cerebellum; for the nerves, girt about with the same meninx from the inner fold or membrane of the tunic, detach and send down fine stamens which not only bind together the fascicles and the enclosed fibres, but also invest the single fibres. Likewise also by the glands, ganglia, and muscles of the body; for these are severally girt about with a manifold tunic, and, from the interior surface of the membrane nearest attached to them they draw forth stamens, yea, a web of stamens, which twines about the enclosed parts and reduces them to a common conatus. *For thus the universal enters into and determines every singular, and a common animus rules in the least particulars of the cerebrum; like as in other compounds, such as the glands, ganglia, nerves and muscles of the body, wherein the engirding membrane gives off shoots, which invest the enclosed parts and at the same time connect them.* This rule follows from truly philosophical principles, which dictate that genera enter into species and species into particulars; that is to say, that universals enter into singulars or superiors into inferiors. That the genera and species of compounds are determined by the quality of the parts and by the mode in which those parts are inter-connected, see Wolff in his ONTOLOGY, § 539; and for the definition of genus and species, see *ibid.*, § 533-534. That the vessels or fibres of the pia mater are cognate or homogeneous with the vessels or fibres of the tunic of the arteries, will be seen demonstrated in the Transaction on the Pia Mater.*

173. *These stamens, or vessels emulous of the fibres, rush forth, fascicle-wise, from the tunic of one artery and inflow into the tunic of another or neighboring artery; and this so compactly that they form a species of membrane wherewith they connect artery with artery and join them together.* Examine merely Fig. 8 [n. 37], where FG, EH, DI, CK and BA designate arteries, while the intervening parallel stamens are the vessels or fibres of which we are now treating.

174. *To these stamens, fibrils detached from the interior layer of the pia mater, seem to add themselves at a perpendicular, and, together with the transverse fibres of the tunics. to weave an entire membranous web.* And this for the same reason as that treated of above, n. 171. Leeuwenhoek himself also makes mention of transverse fibres, and these cannot flow from the pia meninx except at a perpendicular.

175. *In this way, these vessels emulous of the fibre, firmly hold, not only the larger vessels and their offshoots, but also the cortical glands which depend on the vessels, and the fibres which depend on their glands, in a suitable situation, distance, connection, order, law, form, mutual regard, and determination, and in the stream of the general and particular motion; and this, howsoever the cerebrum is expanded, or constricted, howsoever it bears itself, is tumultuous, agitated or smitten: that is to say, whatsoever the action of the sense, the animus, and the will.* For the dependence of all is on the vessels, since on these depend the glands, and on the glands the fibres. Wherefore if the vessels are held connected, the rest also are held; by which connection care is taken that the little appendices and extremities may undulate. The vessels, and also the fibres, are said to be held in the stream of motion, when they are held in a situation that is conformed to the expansory motion of the cerebrum; for from this we can judge what is

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*See n. 168, note, and *cf.* the BRAIN, n. 419, 419 *e*, 419 *h*.

the form of the motion. But on this subject, see where we treat of the arteries.*

176. *And thus preserve, whole and perpetual, the permeability, circulation, and life of the single parts.* There can be no circulation through the vessels of the cerebrum unless those vessels preserve among themselves such mutual situation, connection, and form arising therefrom, as entirely corresponds to the mode of the cerebral expansion and constriction; which means the same thing as being held in the stream of motion. For the cerebral arteries are not furnished with a muscular tunic, like the arteries of the body, but with a kind of nervous and membranous tunic, which is patient† and yielding, and is obsequious to the force of the animation of the cerebrum, or cortical substances. Therefore, in place of the muscular tunic, which, by its own force, impels the enclosed blood stream into the successive ramifications, cerebral arteries of this kind are furnished with fibres, cords, or potencies; otherwise the blood stream would never run through them. But if we would really comprehend these organs of nature to the uttermost, it is of importance that we know the nature of the difference between vessels of the cerebrum and vessels of the body, and between their modes of carrying on their systoles and diastoles.

177. *Fascicles of such fibres, stretched out between the tunics of the arteries on both sides, emulate the motor fibres of the muscles of the body.* That fibres of this kind, stretched out between the larger cerebral vessels, are not so delicate is clear from the description by Leeuwenhoek, who says: "I saw one fibril that consisted of a number of fibrils; yea, a fibril

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*Swedenborg seems here to refer, not to the ECONOMY OF THE ANIMAL KINGDOM, which he had already published, and whose second chapter treats of the arteries and veins of the body; but to a future work dealing, in whole or in part, with the arteries of the brain. See 2 E. A. K., n. 305, where this work is promised. These arteries are the subject of Chapter VI. of the work on THE BRAIN (n. 355 *seq.*) to which chapter and particularly to n. 386-389, 396-400, the reader is referred.

†*i. e.*, manifests a passive quality.

furnished with six sides. . . . These fibrils, I suppose, are also clothed with delicate little membranes. . . . I take it that these cerebral fibrils are easily four times thicker than the flesh fibrils of the ox" (n. 37-38). For they so correspond to vessels that they are more simple among the smaller vessels than among the larger; for nature is present everywhere in her lesser modes and in her measures.

178. *And, like binding and combining cords, they not only connect the arteries in respect to their tunics, but also so extrinsically dispose them, that they perform and keep up their systole and diastole in the most obsequious manner, according to the every nod of the cerebrum.* How these cords, emulous of the motor fibres of the body, direct the alternations of the expansion and constriction of the cerebral arteries, yea, and perfect them, is not easy to understand, unless we are thoroughly conversant with the mode in which the cerebral arteries carry on their systoles and diastoles. For, as pointed out above, these arteries are passive and obsequious to the force of the cerebrum's animation, nor are they furnished with any muscular tunic. On this account, they are opened and constricted by a different force and in a different way, than the arteries of the body; and indeed in such way, that it is necessary that there be intervening cords of this kind to bring aid. They are almost like the cords, called *chordæ Willisianæ*,* which, stretched within the cavity of the longitudinal sinus from side to side straight across and obliquely, prevent the sinus from being expanded beyond a limit [see above, n. 2]; for they are collected somewhat broadly from the tunic of the sinus into a little fascicle which is covered by the tunic,—exactly as is the case with the cords of which we are treating. Thus they govern, contract, and remit every point of the arterial vessel of the cerebrum. *And at the same time, they hold their alternate expansions and constrictions within stated limits, (not unlike the chordæ Willisianæ in the interior of the falci-*

**Chordæ Willisianæ* or *Willisii*, so-called from the English anatomist who first described them. Their use is fully shown by Swedenborg in his work on THE BRAIN, n. 332, 347, 348.

form sinus), and govern them, and, as it were, poise them on the beam of a pair of scales; for they react and draw back just so far as the forces of the cerebrum and the blood enclosed in the arteries acts and produces tension. Hence arises action and reaction, and as many restorations of the state as there are changes.*

179. *The fibres thus colligating the cerebral blood vessels also provide that the vascular or fibrous stamens of which the arterial tunics are woven, be never devoid of their due abundance of perfluent humor. For, by means of these fibres, any portion of the fluid found in the tunic of one vessel, or in the stamen of one tunic, is communicated to all the others, wheresoever they may carry on their action. Thus there is not the smallest hair-like vessel, the filament of whose tunic cannot demand from the public what it needs, and call that common property, yea, proper to itself and its very own, which the neighboring and even the more remote vessels possess and carry. This is of the greatest importance to the cortical glands which, originating from these little stamens, draw out and suck from them their essence and purer juices.* Like as obtains in the tunics, obtains also in the arterial vessels of the cerebrum, that is, in the single branches and offshoots of the carotid and vertebral arteries, which are so interjoined by perpetual anastomosis that of them may be predicated a perfect communion of goods, that is, of blood. And, indeed, such communion, that whatever the trunk carries, this each branch can claim as its own,—for to it is brought as much as it needs; and whatever the branch carries, each offshoot, yea, each least hair-like thread, asserts to itself as its own property. That such is the nature of the communion and commonwealth of the cerebral arteries will be seen confirmed by many considerations in the Transaction on those arteries.†

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*Another name for the longitudinal sinus, the coat of which is formed by the duplicature of the falciform process of the dura mater.

†The reference is, perhaps, to The Brain, n. 355, seq., especially n. 389-392; cf. note to n. 175 above.

As is the communion of the arteries, such, and indeed more perfect, is the communion of the little canals whereof the tunics consist; for these convey their dews to each single cortical spherule; see above, n. 171.

180. *Moreover these vessels emulous of the fibres, forming a species of continuous membrane between the tunics of the cerebral arteries, are like uninterrupted paths and little bridges flung across, whereby there is a connection and continuation of the one with the other. Hence it follows that the sensations, modes and degrees of each single organ, as soon as they are immersed in the medullary lake of the cerebrum, spread themselves out to every point of the vessel, meninx, cortex, and fibre; and thus present to the most simple little brains, that is, to the internal sensoriola, or the cortical spherules, a representation of the image that has been impressed on the external organ, and by the nerves, has been poured forth into the medullary field of the cerebrum,—and this in a type and idea similar to that in which it had been received.* That all external sensations, whatsoever they be and wheresoever laid up, straightway refer themselves to the common sensory or to the cortical substance of the cerebrum, see Trans. I. and II.. [n. 191-195,287]. And therefore, experience adds to reason sufficient proof that these sensations, which are forms of the forces arising from the differences of the purest touches and impulses in the external organs, are elevated by means of continuous nerves and afterwards, when they have left the nerves, by means of continuous medulla, towards beginnings, or towards the extreme ends of the arteries, and this by a path laid down in the fibres.

181. *Behold, then, the manifold uses of these vessels or stamens! And, therefore, it is to be reckoned among the highest tributes of praise due to the illustrious Leeuwenhoek, that he has given to the learned world a knowledge of these fibrils, as he calls them, discovered by the microscope.*

182. But the question arises, Whence is the tunic of the cerebral blood vessels wherefrom these vessels, emulous of the fibre, run forth? Whence are the fibres of that tunic? And also, What kind of humor do they carry? Where do they lay it down? And for what use and effect? But let us take up these points one by one. WHENCE IS THE TUNIC OF THE CEREBRAL BLOOD VESSELS WHEREFROM THESE VESSELS EMULOUS OF THE FIBRE, RUN FORTH? *It is the inmost tunic of the arteries of the body,—that tunic, namely, which interiorly colligates and subtends the rings of the muscular tunic, and which is called the membranous, and by some the nervous tunic. For it is this tunic which is first drawn around the tender arterial canals and is thus the first to be born; and which, in the capillary offshoots, last remains, and is reborn. The carotid and vertebral arteries, as soon as they touch the first bony threshold of the cerebrum, lay aside their muscular and other tunics, such as the tendinous, glandular and vascular,—all of which are the progenitors and fellow workers of the muscular tunic,—and retain this inmost tunic.* As to the tunics of the arteries of the body, see Trans. I., Ch. ii., [n. 116-240, particularly n. 136-147]; and as to this inmost colligator of the rings, *ibid.* n. 187, 188, 189.

183. BUT WHENCE ARE THE FIBRES OF THAT TUNIC? *Under the epidermis, in the stomach, in both lungs, and elsewhere, are most delicate glandular and organic forms, not unlike those of the cortical glands, which are raised up by propagations from the nerves. From these proceed little canals or ducts, emulating fibres, which are reflected towards the vessels of the body, larger and smaller, and which, as it appears, weave this inmost tunic of the arteries and outmost of the veins. These fibres, resuscitated from this origin, are not the genuine fibres of the cerebrum, but, depending on their glands as on renewed origins, they are the re-formed fibres of the body; and hence they are vessels of a middle nature, or vessels emulous of the fibre, and are the genuine corporeal fibres.* Although these fibres are continuations of the fibres of the cerebrum, still the nature of the fibres of the cerebrum is not changed in glands of this kind raised up in the body, except as the vessels of the cerebrum are changed when transformed, by means of the cortex, into fibres. For the whole fibre or fibrous duct that leads or springs forth from this gland, puts on its nature from the prefixed gland and its modes of action, and also from its perfluent fluid. These fibres, therefore, deserve to be called the renewed fibres of the body, or simply corporeal fibres. It would be a long task to follow up the birth of these fibres with the confirmation of experience, nor is this the place for so doing. Meantime, it is a matter of common knowledge that extremely minute glands of this nature are gathered together in the extremes of the body and elsewhere, in such abundance as to form an entire membrane; also that they exhale and absorb an immense abundance of effluvia, which they transmit into the blood; and, therefore, they seem to be reflected towards the blood vessels.

184. WHAT KIND OF HUMOR DO THEY CARRY? *These miliary and highly subtle glands, furnished as they are with little mouths, imbibe from the circumfluent atmospheres and from the inmost essence of the food that is taken in, effluvial exhalations and the primitive elements of salts; and by their emissary ducts, emulous of fibres, they transfer these, by way of the arteries, to the substances of the cortex; and, in fact, as actual experience seems willing to confirm, convey alternately the most chastened lymphs impregnated with saline elements, and the juices and spirits proper and native to the animal kingdom.* Scarce otherwise than as is the case with the lymphatic vessels or thoracic ducts, which freight towards the subclavian vein sometimes pure lymph and sometimes chyle. That such subcutaneous, ventricular, and pulmonary glands in great abundance open wide their little mouths and breathe out effluvial exhalations, is sufficiently obvious from the Sanctorian perspiration; and also from our changes in the daytime and in the night, according to the states of the atmospheres by which we are surrounded. Contagious diseases and many other phenomena also give confirmation to the same effect. I think it established beyond any possibility of doubt, that vessels of this nature stand open in the extremes [of the body] and inmosts of the viscera, and eagerly snatch up the purer essences, and, having snatched them, immediately carry them off, either into the blood, or into the cerebrum.

185. WHERE DO THEY LAY THIS HUMOR DOWN? *In addition to the abundance which they pour into the veins, they carry the purest part up to the cortical glands of the cerebrum, cere-*

bellum and their two medullas, which are raised up and formed from these little vessels, ducts, and stamens at the side of the arteries. Wherefore, by the mediation of these vessels emulous of fibres, the outmost parts of the body communicate with the inmost parts of the brain; and thus the most select and highly purged elementary and animal humor is laid down in the beds and little sinuses of the cortical substances, and is thence derived into the appended fibres. This follows as a consequence from the connection of causes with the things caused. For if the above mentioned elementary glands imbibe, with their open mouths, juices from the circumfluent atmosphere; and if their ductules lead and reach up to the cortical substances by way of the arteries or their tunics; and if it is they that bring the cortical glands into existence; it follows that they carry thither the imbibed essences which cannot but be most highly purged, that is to say, that they deposit them only in the ultimate terms of the vessels or the first terms of the fibres, in other words, in the cortical glands. Experience in respect to innumerable effects proves the same thing. Hence also must be sought the causes of many diseases, such as hysteria, and other [mental] diseases, and certain kinds of melancholia, which from these causes, penetrate into the cerebrum and its imagination, yea, into the reasonings of the mind itself.

186. Finally the question is asked: FOR WHAT USE AND EFFECT? *Namely, in order that they may minister to the cortical glands, as to so many most highly simple and perfect laboratories, the essences and quintessences of purer nature, upon which these glands may pour their own vital essence; from the commingling of which two essences the animal spirit is conceived, prepared and given forth, and is then sent out into the fibres continued from the glands. For this end, the cerebrum looks around for help from its whole circumfluent world, and ingeniously prepares approaches, passages and exits in order that from the mingling of elementary parts with parts that are truly animal, spirits may be prepared that participate in both and possess in themselves the animal and spirituous nature of the body consociated with the elementary nature of* *the world.* But on these matters we shall treat more fully in the Chapter on the Animal Spirit.* The common opinion holds good, that the animal spirit is elaborated from the purest elements of the vegetable and mineral kingdoms, and also of the atmospheric world; and, moreover, that the spirit thus elaborated is not purely elementary but is also animal, and is therefore called spirit; also that this spirit flows down from the cortex into the fibres. How these things follow on to the effect, is now, as I think, explained. It remains only to treat in detail of the matters which have here been spoken of in general; for each detail can be confirmed by abundant experience.

187. *Behold, then, the most excellent and manifold use resulting from a theoretical examination of these vessels; a use which comprehends the arcana of the animal kingdom and also its communications. But still there can be no satisfactory knowledge and confirmation in respect to what we have put forth, unless we have some general anatomical experience; and a specific anatomical experience in respect to details; unless also the physical facts of the phenomena be investigated by means of philosophical series, even to their causes.* Confer. Trans. I., n. 1-117.

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*This chapter is not included in the manuscript of which the present work is a translation. But elsewhere in the author's manuscripts there is a short treatise on the Animal Spirit, which has been published in OPUSCULA PHILOSOPHICA, and translated as one of a series entitled POSTHUMOUS TRACTS.

CHAPTER X.

THE SUBSTANCE, FABRIC AND POROSITY OF THE NERVES, AND THE PASSAGE OF FLUIDS THROUGH THEM.

188. *When cut transversely, the nerves, seen by the glass, appear like a sponge or bulrush, pierced by distinct passages.* That the nerves are fistulous and pervious cannot be doubted, unless we call ocular experience itself into doubt. *But while the nervous bodies are stopped up with their humors, these cavities are not easily detected; for the continuous and coherent parts which constitute the tunics, especially the tunics of the fibres, are hardly discernible from the contiguous parts, that is, from the fluids, which flow through them and between; for the verimost simple fibre which is the all in the compound fibres, is far removed from the sight of the eyes, as will be confirmed in the following pages. Therefore the nerve is seen to open up and distinctly exhibit its cavities to the sight, only when it has been dried out for some weeks.* This is confirmed by the most experienced investigators. Thus Willis says "The nerves themselves, as may be seen by the microscope, are furnished throughout with pores and passages, as with so many cavities thickly set in, and mutually contiguous. Thus their syringe-like substance, like Indian cane, is everywhere porous and pervious," (n. 8.). It is the common opinion of all investigators that animal spirit flows through the nerves with the utmost freedom, and it is because of this that Descartes supposes that the nerves have valves,—a supposition mentioned by Bartholin, together with his own strictures thereon, see n. 13. In respect to the porosity and permeability of the nerves, there is among the learned, no more sharpsighted and deeply inquisitive investigator than Leeuwenhoek; for this observer has set under his microscopes nerves that were first dried out, and were then dissected at various planes, and in some of his figures he shows their structure with the interstices between them; see his figures, 1, 2, 3, 4, 5, 6, 7, 8, and the descriptions thereof in n. 27, 28, 29, 30, 32, 33, 34, 35, 43. The reader should examine all these figures and read the descriptions before he accompanies us any further.

189. *Wheresoever in the body there is a nerve, it is made up of fibres, fascicles of fibres, tunics, and connections; and it arises from the cortex and the gray matter of the cerebrum, cerebellum, medulla oblongata or medulla spinalis, and is produced and continued through their medullary substance.* That every fibre springs from a gland of the cortex, has, I think, been sufficiently confirmed above; moreover those who, as far as possible, have made examination of the matter with their own eyes, are of the same opinion. This, then, is a description of the nerve from its origin or genesis.

190. *The fibre is the principal substance of the nerve. Compacted together, fibres constitute the very body or medulla of the nerve. A larger or smaller number of fibres covered over with a common membrane, forms a fascicle, also called a nervule and the beginning of a nerve. Such fascicles, compacted within a still more general tunic, produce an entire nerve. When such nerves are brought together under a most common sheath, then arises a nerve trunk, such as the sciatic nerve and the brachial.* That such is the composition of the nerves, is evident from dissection of the several nerves.* Simply consult the famous investigator, Leeuwenhoek, and his figures. That such is the fabric of the nerves, is also clearly evident from their coalition at the point of their origin and inauguration; for delicate fascicles or beginnings of nerves go forth from the medullary stem from which they have been excluded and a number of such fascicles converge together under a common tunic drawn from the dura mater.

191. *Thus we see that a nerve, like all other created bodies in the universe, grows by degrees from its lines, simple substances or fibres, into its dimensions, and springs up distinctly in a three-fold way into a body. That the lines or fibres also arise from their points multiplied together and drawn out*

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*In the Latin this sentence is printed in italics.

lengthwise, is clear from the origin of the simple fibre. These particulars are conformable to purely geometrical principles, since, for the existence of a line, there must first exist a point, for the existence of an area, there must by all means be lines, and for the existence of a cubical body, we must have areas; for it is the multiplication of points, lines and areas that produces dimension. In order that we may obtain the square of a cube, and the cube of a cube, it is necessary to assume cubes as simple substances or points. So in all respects is it in the nerves.

192. *How fistulous and sparse is the structure of a nerve is clearly evident from what has been said above; for the fibres themselves, [of which the nerve consists] are pervious and channeled.* See above, n. 142. *There are interstices between the fibres, and still larger interstices between the fascicles of fibres; for fibres are little canals not agglutinated with the neighboring canals, and fascicles are smooth cylinders distinct from the contiguous cylinders.* There are some who have imagined that a cavity goes through the middle of the fascicle as is the case with an artery, but this view is not supported by experience; for the fascicle is permeated, not by one cavity, but by innumerable cavities. It is, indeed, possible that a somewhat more ample space may be formed in the middle of a nerve, caused by stagnant serum, or by the swelling of the vein that runs through it; but this is unnatural and no induction can be made from the unnatural to the natural. That there are passages between the fibres, and between the fascicles of fibres, is shown by the mere geometrical figure of these bodies; for when little canals and smooth cylinders are joined together they must necessarily give rise to some intervening space, and unless this space were permeated by fluids, the sides would certainly coalesce and become entirely collapsed, an eventuality which is contrary to experience. The reader should here carefully examine Leeuwenhoek's figures 1, 2, 3, 4, 5, 6, 7 [n. 29, 30, 32, 33].

193. *Inasmuch, therefore, as each fibre and each fascicle of fibres flows from its own proper origins in the brains, and* *goes down to the performance of its own proper offices in the body, it is necessary that each fibre and each fascicle be distinct from its accompanying and neighboring fibres and fascicles, and be non-contiguous thereto except at the points of contact. Otherwise the several forces and actions would coalesce in a confused manner into one general indistinct force and action. And, therefore, in proportion as one fibre in its action is distinct and free from another, and one fascicle from another, the better is its condition and state, and, consequently, the condition and state of the whole kingdom; that is to say, the more obsequious the muscle to the decrees of the brain and of nature, the more apt the gland for the purification, separation and commingling of liquids, the more prone the artery to the fulfilling of its systoles and diastoles, and the more suitable and accommodated the organ for receiving sensations, transferring them, and distinctly representing them in the cerebrum. Such is the state of the fibres, fascicles, and nerves in the flower of youth, but it is wholly different in the winter of old age.* For old age arises from an obstruction of the arterial and venous capillaries and the coalescence of the fibres and fascicles; hence the fibres, both the muscular and others, acquire a hard and tendinous nature, the consequence whereof is that the several forces no longer enter into the general force; and according as the forces are, such is the resultant action; therefore is the vigor of old age so far removed from the vigor of youth.

194. *As many, therefore, as are the apertures lying open in a cross section of the nerve, so many are the pathways constructed for the fluids. But to investigate the nature of the fluid which runs through the fibre, of that which runs through the interstices of the fibres, and of that which runs through the interstices of the fascicles,—this is a work, and here is labor. It is an evident truth, however, that the humor permeating the spaces between the fascicles is not the same as that which permeates the little spaces between the fibres, nor as that which permeates the little channels of the fibre. But, from diligent consideration of the several points, it seems* *possible to conclude that through the interstices of the fascicles flows the genuine serum of the blood, impregnated with urino-saline or fatty particles; between the little interstices of the fibres, a highly rectified humor rich in ethereal and subtly sulphureous principles and elements; and through the fibre itself, that middle vital essence called the animal spirit. But as to the origin and nature of the one humor and the other, this is not a matter to be learned by light study, nor to be delivered in a few words; nevertheless we may be permitted to make the attempt, for otherwise we shall not reach the end or goal.* That these passages are traversed by humors of diverse character, may be argued from the diversity in the situation and figure of the several parts, and from many other indications. For the more ample the space, and the more remote from the centres, the grosser the humor; thus the most chastened humor, the loss whereof is most greatly to be feared, must necessarily flow through the middle of the fibre. In the meantime, we may form a judgment from the tunics and walls as to the nature of the fluid that transpires through them; for the fluid, which is prior both in time and in nature, constructs for itself pathways and accommodates them to itself. Trans. I., n. 134, 135.

195. *But before entering this field, it is necessary to minutely search into the nature of the fabric and porosity found in the medullary substance, and of that found in the cortical substance of the cerebrum, cerebellum, medulla oblongata and medulla spinalis. For it is from this origin that the fibre is drawn, and from the same origin is introduced that humor which penetrates the spongy bodies of the nerves; for the two mutually correspond to each other; and in the nerve is presented the effect, which is the continuous effect of its cause in the brains.*

196. *As regards the fabric and porosity of the* MEDULLARY SUBSTANCE, *its fibres and vessels mutually consociate, and distinctly enfold themselves into reticular plexuses; for there are lesser plexuses within the larger, and each is girt about by the softest little membranes.* See what was adduced above, n. 131. *Hence arises a structure, loose, spongy, pervious to lymphs, bibulous, soft, capable of expansion, free to act, and peculiarly* *suitable for building up the nerves;* see above, n. 132. *Thus it is apparent with what distinctness the cerebral medulla conducts to the lattice-work of the nerves, the humors received from the cortex. For each fibre, there most freely fluent, transmits its own spirit; each lesser plexus woven of the loosely fluent fibres, pours in between the fibres of the nerves, a humor of the utmost purity; and each larger plexus pours in, between the fascicles of fibres, its own oleaginous serum. And to the end that these liquors shall not break away from the paths marked out for them, the several plexuses are surrounded and guarded by a delicate tunic. When these plexiform fascicles emerge from the medullary stem, they are first surrounded by a fine meninx, and afterwards by a hard one. Thus the most diligent care and precaution is taken to prevent the enclosed humor from flowing off elsewhere, and to ensure its being determined by distinct paths into the corresponding pores of the nerve. Nature also, from the very cradles of the fibre, strives after the same effect; for the several fibres, newborn from their cortical glands, quickly join company ana submit themselves to a common covering. Thus the fabric and porosity of the medullary substance in the brains corresponds to the fabric and porosity of the nerves in the body; nor is there any other difference between them, except that the fibre of the brain flows much more free of action, while the fibre of the nerve, being more closely compacted, is coerced by bonds, to the end that it may serve and minister to the brains.* Confer the observations made above, n. 193.

197. *As regards the* CORTICAL SUBSTANCE, *from which, as from their beginning, the fibres flow down, and from which, as from their fountain, the humors are derived, each of its glands is separated from the neighboring glands, and circumscribed by a little space; and each of its lesser congeries or clusters is trenched about by fissures and little furrows; and each larger congeries or cortical glome, is surrounded by deep and winding fossæ.* This is evident from a mere inspection of the cortex; for as to the separation between the glands, this has been proved by Vieussens and other anatomists by means of their black injections [n. 17]; and as to the fissures and sulci which distinguish the clusters from each other, this is plain to be seen merely from the division of the parts in boiled brains; confer Trans. II., n. 135. *Thus the cavities found between the fibres and between the fascicles of fibres, and finally in the nerves, take their origin all the way from the cortical substances, and are continued into the nerves. The cortical gland itself is furnished with a little follicle or minute chamber, through which the middle vital essence, that is, the animal spirit, transpires into the medullary fibre of the brain, and the nerve fibre of the body. From the space which circumscribes the gland, a highly chastened humor, rich with principles and elements subtly sulphureous and ethereal, flows down between the fibres; for no other way is open to it; and therefore each gland is seen to be constantly anointed by a moisture of this kind.* This is confirmed by Pacchioni, who says: "If you touch the cortex of the brain with your fingers, you will not fail to notice that it is extremely smooth as though suffused with a most subtle oil, a fact which I have learned, not without admiration, from a vast number of dissections of cadavers." (Trans. II., n. 88.) And, therefore, Leeuwenhoek calls this substance not only vitreous, but also oleaginous; and he states that it gives off an odor of sal-ammoniac [n. 22]. Moreover, if a substance so prone to agitation and animation, were absolutely dry, it would be rendered impotent of action, and become coalescent with the neighboring substances. *From the fissures and commissures whereby the larger congeries of glands are discriminated, there is derived a genuine serum, impregnated with urino-saline and fatty parts, which flows down between the fascicles of the nerve fibres. For this purpose the arachnoid tunic is extended over the pia mater, in order that it may pour on a lymph of a better quality.* That the arachnoid tunic performs this use, will be seen in the following Transaction. [n. 352-354 below.] For the rest,—that the pia mater perpetually expires a most subtle dew, is confirmed by much testimony by Pacchioni, Ruysch and other anatomists; and that the medulla assiduously receives the humor of the cortex, and the nerves the humor of the medulla, and transmit them to every point, see Boerhaave,

n. 49, *sup. But humors of a grosser character, namely, those serous and pituitous humors which crowd the winding fossæ, are carried down the larger plexuses of the medullary substance, and by means of animations or alternate expansions and constrictions, are urged on to their outlets which have been constructed by nature.* This is plainly to be seen in the encephalon, and also in subjects laboring under cerebral dropsy; for the medullary substance, being loose and patulous like a sponge, receives the purer juices within the structure of its plexuses, but the grosser between the plexuses themselves, that is, in the interstices shown in Fig. 14 [n. 40], by H, I. When, therefore, this somewhat gross and pituitous humor penetrates the plexuses, it inevitably falls into the larger interstices of the nerves, whence arise inflammations, swellings, and certain kinds of paralysis; but when, on the other hand, the humor enclosed in the plexuses escapes, by the laceration of the tunics, into the larger spaces I, H, the result is that the lack of such humor in the nerves gives rise to torpor, impotence, emphraxy,* etc. As to the outlets constructed by nature and to which this pituitous humor is urged, this will be explained in the Transaction on the Brain.† *Thus the cortical substance corresponds in all respects to the medullary, and the medullary to the nervous; and, by the principles or beginnings, everything is provided which conduces to the effect.*

198. *But it is asked, Whence come such diverse humors? What is their nature? By what force are they carried down into the nerves and through them? and What use do they perform?*

199. *With regard to the first question,* WHENCE COME SUCH DIVERSE HUMORS? *It is well known that a better, lighter, softer, and more perfect blood is continually being drawn up towards the brains, and this through the carotid*

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*The total obstruction of a cavity or canal by matter of a viscous nature. The name is derived from a Greek word meaning to obstruct.

†Cf. THE BRAIN, n. 578, 518g, 593, 595, 597, 598, 600, 602a, g. h.

and vertebral arteries, which after constant ramifications, approach and enter the very glands of the cortex. Hence it follows that these diverse kinds of humor spring solely from the blood. If now we consider the globules of the blood as to their inmost structure, it will become evident that each globule carries in its bosom all those kinds of humors that are transmitted through the pores and passages of the nerves. Thus it is apparent how important it is to know what is the structure of the blood globule, and what the principles and elements of which it consists. Microscopic experience has already opened to us the way almost to the inmosts; and it has taught us that a globule of red blood is made up of smaller globules and these again of globules still smaller; and that these several globules are bound together by suitable particles, borrowed from the kingdom of salts and sulphurs, whence results the spherical shape of the blood, its redness, gravity, heat, volubility, flexibility and solubility. The composition of the blood globules has already been treated of at some length in Transaction I, where it was shown: That in the blood is contained whatsoever exists in the body, n. 2, 3, 5, 59-61, 115. That in its globule are contained many kinds of salts, n. 43-45, 91, 92. Concerning its composition in particular, see n. 91, 92, 95, 96, 188, 371. That the blood globule consists of six other globules, and these again of many smaller ones, was seen by Leeuwenhoek with his glasses and he gives a delineation of the globule itself, [n, 22, and Trans. I, n. 29-30]. To the above it remains only to add, that in the blood globule are found saline elements, but not lymph; for the latter serves as a vehicle, and carries to the blood the things of which the blood is constructed. This lymph, impregnated with saline parts of divers kinds, is called serum. Thus serum is not in the blood but the blood swims in and is surrounded by serum.

200. *Being thus fabricated, the blood globules readily suffer themselves to be resolved and divided into their constituent parts; and they are, in fact, resolved at every circulation, especially in the brains, whither the better and softer blood flows. Hence it follows, that from the resolved globules and the affluent lymph, result the various kinds of humor* *enumerated above; in other words, that the true blood globule, divided into its elements, steals into and runs through the porous structure of the nerves by distinct paths; so that nothing of the genuine blood is lost, until it has performed its use in the inmost penetralia and medullas of the whole animal kingdom.* On these points see above, Transaction II, n. 128-131; but that they may be more fully confirmed, I wish at this place to bring together the experiences of Leeuwenhoek, as described by himself, who more than all other men has labored to open up the intricacies of the blood globule.

"I was able (he says) to distinguish in a butt* various blood particles which had been disrupted; and in some I was able to distinctly discern four and five, and in a few cases even six particles. But what I thought worthy of note was the fact that many of these sanguineous particles which presented themselves to my sight, were of an oval figure, certain others were somewhat roundish, and others again were perfectly spherical. . . . I constructed a globule of this kind† (he says) consisting up six globules, each of which was again made up of six globules, in order to set before my eyes the curious structure of these blood globules. I hold, therefore, that each single globule of our blood consists of at least thirty-six globules. When moved, and pressed, these globules, being flexible, are mutually pressed against each other, [and take on a perfectly round shape‡]. But who shall say by what arrangement this is effected? For howsoever minute the parts into which, in imagination, we divide this globule of the blood, nevertheless the particles of which the globule consists may be infinitely smaller." [*Continuatio Arcanorum Naturæ,* Lugd. B., 1719, p. 217, 222.]

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*Butts are the fry of plaice and flounders.

†Leeuwenhoek here refers to one of his figures which shows four globules in mutual juxtaposition, with a fifth resting on the four and over the space between them; a sixth globule is understood as being situated on the opposite side directly opposite the fifth. Each of the globules seen in this figure is marked by lines to indicate that it also is made up of six globules, the sixth, of course, being again left to the imagination.

‡Leeuwenhoek here gives a figure showing the six globules so compresed as to combine into a perfect globule or ball.

"I took a little oil of a yellow color, which had been expressed from the bark of the cinchona* and afterwards mixed it with a little blood taken from my thumb, and, as quickly as possible, set the mixture for examination under the microscope. I immediately observed that some of the blood globules were coagulated and mutually agglutinated. Moreover, I saw, floating in this same humor or liquid, a large number of blood globules which were not only clear and pellucid beyond measure, but also, what is of more importance, in the case of each one of these globules I could most distinctly see that it consisted of other and diverse globules. These sanguineous globules presented a delightful appearance, especially when I set them moving before my sight, for not only could I distinctly behold the globules, but frequently I was able to note with the greatest accuracy, the juncture between the globules composing the blood globule; there somewhat of obscurity was seen, but the rounded eminences of each single globule again presented a clear light." [*Cont. Epistolarum,* Lugd. B., 1696, p 121.]

"I cut some pieces of the root of the pareira brava† into exceedingly minute bits, and pouring rain water over them I set them on the fire to boil. After the water had stood quiet for some little time, in order to allow of the films or layers settling, I put a small drop of it, about as much as would cover the head of a pin, on well cleaned glasses; with this I mixed a drop of blood drawn from my finger by a needle-prick. I then saw that the globules which give the blood its redness were more scattered in the blood thus diluted, than I remember to have ever observed before. But what seemed to me most remarkable was the fact that a number of the globules were indented with a kind of a curve or sinus, just as if we should take a bladder full of water and by putting the finger on

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**i. e.,* Peruvian bark.

†The cissampelos pareira of Linnæus; a species of yellow sarsaparilla, native to Brazil and the West Indies.

the middle, produce a hollow cavity or trench. When those scattered globules, now of a flat shape (for when they lie sparsely scattered about, then, by reason of their exceeding softness, they assume a flat shape),—when these globules draw closer together, they sometimes assume an oval shape, in which case also those curves or sinuses spoken of above become somewhat lengthened out. But when, on the other hand, the globules are coagulated or stuck together they exhibit the shape of a solid body, none of the parts of which can be distinguished by the eye. [*Epistolæ Physiologicæ,* Ludg. B., 1718, p. 420.]

"I found the blood of the spider to consist of plano-oval particles swimming in a clear liquor. Many of them had in the middle a shining oval lumen; others seemed as though they were made up of several roundish ovals of unequal size; others seemed to be almost entirely surrounded by minute globules; while others had no globules at all in their circumference, but had them in their middle." [*Arcana Naturæ,* Ludg. B., 1696, p. 54-55.]

"While I was observing the blood flowing out of the amputated legs of a spider, (after having for some time fixed my eyes intently on this blood, during which time a thin liquor was being extracted therefrom), I saw saline particles coming from the blood, which particles, when gathered together, presented the appearance of twigs or branches. It was a by no means unpleasant sight to see these saline particles, many of which seemed to take their origin from one single point, as it were, that is, from one single sanguineous particle, frequently joining together and presenting an appearance like the branches of a rosebush. [*Cont. Arc. Nat.,* 1719, p. 330, 331.]

"I take it for granted that those perfect globules which impart the redness to our blood, are of such size that one hundred of them placed side by side in a straight line, would not equal the thickness of a little grain of sand; hence it follows that a million globules of the blood would equal one coarse grain of sand. I now observe blood-vessels in the brains, in respect to which I am positive that if one globule of the blood were divided into sixty-four parts not one of these parts would be able to traverse any of the little vessels; for if I put the diameter of these vessels as 1, and the axis of the blood globule as 4, then it would mean that even if a grain of sand were divided into sixty-four thousand* parts still it could not enter the minute blood-vessels of the brain, especially if the minute particles of the blood were *not flexible* but rigid. I nevertheless think that this kind of minute blood particle always enjoys flexibility like those blood globules which have arrived at perfect maturity." [*Arc. Nat.*, Ludg. B., 1696, De Structura Cerebri, p. 35.]

In other places also Leeuwenhoek states on the ground of his experience that hard, compact and indissoluble blood presages death, but soft and soluble blood the finest health. [*Philosophical Transactions*, an. 1675, n. 117, p. 381.] He also affirms that he has seen with his own eyes a blood globule divided into lesser globules. These statements have also the consent of Boerhaave, *cf.* Trans. I., No. 31. [See further citations from Leeuwenhoek, in n. 22-25, *sup.*] But let us continue the thread of our discourse.

201. *The next question is,* WHAT IS THE NATURE OF THESE DIVERSE HUMORS? ***The inmost and genuine essence of the blood is the verimost animal, vital, and spirituous essence, which alone rules in the globule, and which acts therein from itself and its own nature. This principal substance of the kingdom courses through the simplest fibres, and the cortical substance continually pours into it a new substance conceived in its purest wombs and laboratories. This principal, and first, sole, inmost, supreme, most universal, most simple, and most perfect substance of the animal kingdom, comprehends in itself all that principle and nature which is found contained in the posterior and compound substances of its kingdom; and, therefore, to search into its character is to search from principles into the whole anatomy, pathology and physiology of the human body.*** This substance, or this truly animal essence, has been treated of in Transaction II., Ch. 3, [On the Human Soul, n. 208 *seq.*]; and that it is this which rules from principles in each blood globule see the same Transaction, n. *222*, and other references there cited.

**Myriad,* literally "ten thousand."

202. *The second or middle essence, that springing from the divided blood globule, is that essence which is called the animal spirit. It is made up of purest elements and principles subtly sulphureous, and ethereal, commingled with the genuine animal essence mentioned above; it is also the same as that essence of which the pellucid globules of the divided blood consists. This fluid substance makes its way through the middle of the little sinus and minute chamber of each cortical gland, and courses through the little canal of each fibre.* But with respect to the animal spirit, the reader will see a special transaction on this subject.*

203. *That most chastened humor which runs through the interstices of the fibre, consists of those purest elements, subtly sulphureous and ethereal, mentioned above, which result from the lesser and divided globules of the blood; on which is besprinkled a highly defecated lymph; in this way a highly pure serum is brought into existence, which serves for integrating the pellucid blood and perfecting its globules The subtly sulphureous and ethereal elements are the simplest and primitive parts of salts floating about in the ether.*

204. *But the somewhat gross humor which is carried down in the interstices of the fascicles consists of urino-saline parts, from which oil and fat is made up, and of a lymph, collected under the arachnoid tunic, which is poured on. Thus is born the genuine serum of the blood, which serves for the construction of the red globules. The urino-saline parts are the secondary principles of salts, which are taken from the atmospheres and the aliments stored therein, and which come forth from the red blood globule when resolved.* These are the parts mentioned by Leeuwenhoek, (n. 200 *sup.*), as breaking out in such abundance from the blood globule of a spider. Hence it is clear why we must be constantly nourished by aliments; that is to say, solely for the sake of the blood, to the end that it may come into existence, and that, whenever it is resolved, it shall again be made whole. The lymph is the vehicle that conveys, applies, and insinuates these aliments. *From these considerations now follows the conclusion that all the humors that pass through the pores and lattice-works of the nerves come solely from the opening up of the blood; so that what runs through the porous and spongy structures of the nerves is the blood globule divided.*

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*The little work on THE ANIMAL SPIRIT, published in POSTHUMOUS TRACTS, is probably the Transaction referred to, or a first draft thereof.

205. *But for an intimate and minute knowledge of the nature of the several humors, it is necessary to open up the whole of natural chemistry even to its very principles. There we find only one thing that is universal, namely, that the primitive saline elements, or, what amounts to the same thing, the sulphureous and oily elements, are least and most perfect cubes, squares and trigons, the sides of which are hollowed out to suit the convexity of globules. Thus they are parts which, being angular, are themselves inert, and neither mobile nor flexible; and which serve active substances as an instrumental cause, and are most exactly accommodated to the whole nature, mode and form of compounds.* Respecting the generation, formation, derivation and figure of saline, sulphureous and oily parts, see Transaction I., n. 67-79.

206. *Then comes the question,* BY WHAT FORCE ARE THESE DIVERSE HUMORS CARRIED DOWN THROUGH PASSAGES CONSTRUCTED FOR THEM IN THE NERVES? *In the cortical substance, this is effected by means of the expansion and constriction of the glands, that is, by means of the animation or alternate respiration of the cortical brain.* That it is the cortical and cineritious substance that is expanded and contracted, or that is the origin of the brain's animation, [is evident]; for each of its spherules is like a little heart prefixed to its fibre, not unlike the great heart of the body prefixed to its arteries. And since there are as many origins of motion as there are spherules of this substance, therefore, when these are expanded, the whole mass of the conglobated viscus, namely, its surface and blood-vessels and its whole inner medulla, is contracted, and vice versa; see Trans. II., 132-146. *In the* *medullary and nerve substance likewise; for each fibre, like an artery, drives its fluid into the parts that follow, and like the cortex, it has its alternations of expansion and constriction.* See above, n. 135, 146; and respecting the alternate respiration of the cerebrum, see Trans. II., n. 1 *seq.* [On the Motion of the Brain.] *This most pure humor between the fibres is urged to its outlets by the alternate expansion and constriction of the fibres; for it is not fluid of itself, and therefore is pushed forward by the highly active force of the fibre. For suppose we have smooth canals closely joined together, and between each canal an interstice; it would then follow that when the canals are expanded, the humor flowing without and between them will, by virtue of this expansion, be pushed forward. So also is it with the somewhat gross serum which flows between the fascicles of the fibres,—a serum which is as yet of a somewhat sluggish and inert nature, because impregnated with somewhat large and uneven particles. And therefore, when the fibres remain inactive, and a rude and undigested humor stops up and obstructs the passages, there arises fat which interposes itself between the fascicles of the fibres.* That in fattened and sluggish animals the interstices of the fascicles are filled with fat, see figure 2, and Leeuwenhoek's description thereof. [n. 29.] That urinous and volatile salts give birth to such fat may be shown by many proofs, but here is not the place for making this excursion; it is apparent however, from the fact that when the blood is resolved by chemical means it goes off into a thin and a somewhat gross oil, according to the experiment cited in Transaction I., n. 30, 34. *This is the efficient cause of the trajection and circulation of humors through the nerves; to which is added an auxiliary and promotive cause arising from the respiration of the lungs, which organs wonderfully concur in the transfusion of this juice through the nerves.* Confer Transaction I., Chapter I., [On the Composition and Essence of the Blood], and n. 172-176 above.

207. *Lastly, comes the question,* For what use? *The use is manifold, namely, that, at every circulation, the blood may be opened up to its very principles, and may as often return* *to its parent spirit and commence anew; to the end that it may be adapted to every use and formation,—for the blood is the treasure-house and seminary of all the things in its body; that it may continually supply the spirit that animates the fibres and courses through them; that it may excite the motor forces and convey to the mind the modes, forces, and forms of sensations; likewise that the different kinds of juices, such as saliva, chyle, milk, bile, the genital fluid, and many others may be rightly prepared in the glands. And therefore, as soon as the blood is defiled with heterogeneous matters, and begins to grow hard, and no longer suffers itself to be unlocked in distinct manner, the universal animal economy labors, and from cacochymia** *arise dire diseases of head and body, such as paralysis, atrophy, stupor, ataxia, phrensy, cephalalgia or headache, lipothymia,*† *fevers, inflammations, phthisis,*‡ *and so forth,—for there are a host of them.*

CHAPTER XI.

THE TUNICS AND LIGAMENTS OF THE NERVES, FASCICLES AND FIBRES.

208. *That each nerve is invested with its own tunic is evident, being recognized by the naked sight; but that each fascicle of fibres, that is, each nervule is also clothed with a membrane can hardly be detected without the aid of the microscope.* That the nerve is discriminated into principles or fascicles is not apparent to the naked eye, and still less apparent is the tunic of the fascicle; but that this fascicle like the nerve itself is also wrapped about, or tunicated, is declared by that keenest of observers, Leeuwenhoek, on the evidence of his own sight. His words are, "As I have often observed, each nervule is assigned its own separate place, and is covered about

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*An abundance of depraved humors in the blood.

†A sudden cutting off of the vital forces resulting in faintness, and, at the worst, in syncope.

‡Progressive emaciation; the word is generally used, however, as meaning *phthisis pulmonalis*, that is, consumption.

with its own little membrane, exactly as we have declared with respect to the fibrils of fishes and to the fleshy fibrils, namely, that they are all invested with their own little membranes" [n. 39]. And inasmuch as they are smooth cylinders and mutually separated from each other, and between them are interstices through which flows a humor, it necessarily follows that each one of them is covered over with its proper tunic; otherwise there would be no fascicle, nor nervules, nor principles of nerves.

209. *But that the fibre itself is girt about by a certain most delicate meninx is a fact which is not apparent even to the most highly armed sight, and which our imagination can hardly perceive. From analogy, however, it may be concluded that the fibre is a subtle membrane; for it is a little canal and transmits spirit, and it is distinguished from the neighboring fibres by a little triangular interstice through which flows a rectified humor.* This purest little membrane of the fibre is also declared by our author Leeuwenhoek, to have been discovered to him by the microscope. He says, "The extremely minute vessels, of which, for the most part, the nerve is contextured, are also clothed with their own little tunics, not unlike the veins and arteries; but these little tunics are not conglutinated or coalescent with each other" [n. 39]. The same is also confirmed by Bartholin, who says: "The nerves, moreover, without exception, consist of many nervous fibres or filaments mutually held together by little membranes" [n. 13]. *But as seen by the microscope, the membranes of the fibrils appear no otherwise than as a kind of sluggish and viscous humor; for they are most highly delicate, and, therefore, emulate the nature of a fluid rather than that of a solid.* Such is the case with all substances in prior nature, which substances may yet be called inert when compared to the supreme fluidity of more active entities. Such substances, although they are fluid, yet, when gathered together and composing one larger body, appear as though consolidated and hard, because, taken together, they offer a strong resistance to the touch and to every assailing force. It is resistance that gives esse to the solid, the hard, the material, and the body, to which esse extension is thus necessarily adjoined. That this membrane is fluid is also testified to by Leeuwenhoek, who says, "Those fibrils, of which, as parts, the nerve is made up, are clothed with a certain mater for which I see no more suitable name than little membrane" [n. 33].

210. *But because this tunicle is the most simple of all the tunics of the body, it seems* to consist of fibrils pure above every imagination.* If the fibre of which we are now treating be a little canal, and its circumambient membrane consist of the most delicate threads or shades of threads, it follows that these lines emulous of filaments are simple fibres,—fibres, namely, than which there is nothing more simple in the animal kingdom. But the simple fibre will come to be treated of separately in its own chapter. To the preceding may be added the remarks made in n. 190 above. *But we must proceed in order, treating first of the tunics of the nerve, then of the membranes of the fascicles, then of the most tender meninges or delicate sheaths of the fibres, and, finally, of the ligaments.*

211. *The tunic of the nerves, as is obvious to the naked eye and to the touch, is double or triple; for the outmost tunic may be easily separated from its trunk, but not the inmost, which is closely adherent. This tunic of the nerve is the dura mater itself, which is superinduced when the nerve, in the course of its exit from the brain, perforates the cranium, or when it breaks out from the dorsal spine through the spaces between the joints of the vertebræ. This dura mater consists of two or three layers, which distinctly separate from each other when the mater invests the nerve, and also when it invests any of those sinuses which are called sinuses of the dura mater.* That the dura mater is a double or triple membrane is recognizable by the touch of the fingers; for if it be rubbed between the fingers in contrary directions, it is evident to the feel that the one layer as it were recedes from the other. This is still more clearly evidenced in the sinuses which are invested by the inner membrane and covered over by the outer. The same is also confirmed by the directions of the fibres of the dura mater, in that they do not run out in a like direction and order. Convinced by these circumstances, investigators assert that this mater is a double membrane, and some that it is even triple. That it is triple is not very far from the truth; for there is an intermediate layer which is vascular, since arteries flow between the two layers and join them together. Perhaps also this arrangement still persists in the ramifications [of the dura mater]. These layers of the dura mater are not easily separated from each other, except in those places where necessity itself has laid down the law; as, for instance, where the dura mater encloses the sinuses, and where it wraps itself about the nerves; in the latter, when unbundled, this is quite apparent, the outmost tunic being torn off or coming off almost spontaneously, but not the inmost.

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*It may be remarked that the word *videtur* translated *it seems,* does not necessarily imply the doubt suggested by the English words; it might equally well be translated *it is seen.*

212. *But this tunic does not remain the same throughout the whole extension of the nerve in the body, as it was in its origin, but is changed and reformed.* These points will be dealt with in the next chapter. A nerve's quality which shall be adequate to its functions in its extremities, depends not only on the enclosed fibres and their nature, diversity, position and quantity, but also on the investing tunic; for it is this latter which tempers the forces of the fibres, that is to say, which tempers the degree of these forces. The cause of the quality must, indeed, be derived from the brain, whence is the beginning of the fibres and nerves, but it comes also from the body; for principles and causes regard effects as though these were present in themselves, and were of a quality corresponding to themselves; thus the means, that is to say, the nerves, are formed in due ratio to the extremes. The quality of a nerve is therefore varied according to the use which the nerve performs in its extremity. Hence it follows that one nerve is never entirely like another. *And this, according to every use in the extremes; and it becomes either a nervous, a muscular, or a tendinous tunic; that is to say, it becomes more or less active or passive.*

213. *But to resume. For the weaving of the tunic of an entire nerve every kind of vessel and every kind of fibre is used.* Boerhaave is also of this sentiment; see what he says, n. 46, above. For there are little vessels, especially of the cerebrum where they are called the arterial vessels of the dura mater, which accompany the outgoing nerve, see above, n. 105; moreover, in the body also many vessels insinuate themselves. There are also the vessels of a middle nature, that is, vessels emulous of the fibre. Moreover, genuine fibres insinuate themselves into the tunics, and this especially in the ganglia, where they make a kind of turn, and where the old membrane, that is, the membrane of the brain, is put off and a new one put on, as will be shown in the following chapter. Moreover, all this is necessary to the nerve, which rouses up everything in the body; and, therefore, for the building up and maintenance of the nerve everything prior and everything posterior must concur, in order that the nerve may act as the middle cause.

214. *And thus the nerve, before it emerges from the soft brain where it acts in the greatest freedom, is guarded by a sufficiently strong covering and defended by a breastplate; and this to the end that, when it lets itself into the field of motions and effects, that is to say, into the body, where reign inequalities, mutabilities, disturbances and discords, it may be immune from every danger.* In the brain all things are tranquil, and as though in their birth, for there rule, principles, forces, and causes; but in the body are the ultimate effects and motions of the causes, that is to say, a more imperfect nature, see Transaction I., n. 615; and, therefore, also the two kingdoms, that of the brain and that of the body, are held most distinct from each other.

215. *The tunic of the fascicles, which is not so obvious to the senses, is likewise double,—I dare not say triple. This follows as a consequence from the analogy of its compounds; for as is the case of a nerve in respect to its nervule, so here is the case of the nervule in respect to its fibre, which is a most simple nervule. The like also obtains in the cerebrum, cerebellum, medulla oblongata, and medulla spinalis; moreover in* *the muscles and glands, and also everywhere else in the body. For such as nature is in the greatest things and those obvious to the sense, such also she is in the lesser, yea in the least; and thus, such also in the fascicles, yea, in the fibres,—with a difference solely of degrees; and this rule so far holds good in superior things, that these must be extricated, explained and understood by means of analogies.* Confer Trans. I., n. 629-632. The recognition of the tunic of the fascicles as being a double tunic is not opposed by the delicacy of this tunic, nor by its degree of consistency so nearly approximating to fluidity; for substances, compounds, and series of purer nature know not what the hard and the solid is, as these come to our apprehension by contact with the senses. Moreover, they may be fluent, and yet, among themselves, have concordance and consistency, for they are placed beyond every fear of lesion, and every chance of danger; that is to say, they are set, as it were, in the state of their integrity, and in a state which is free for action and for passion.* For compound substances, which in themselves are mutable and of themselves uneven, nor ever consistent with each other, cannot act upon the more simple substances of which themselves are the compounds; this would be contrary to nature, to every physical law, and to the decrees of philosophy. But it is the simple substance, that is, a substance that is more simple than its compound, which acts into its compound. This is most evidently apparent in the first formation of the chick and the embryo; see Transaction I., n. 248. It is also apparent in the vesicles [of the primitive brain of the chick and embryo]; for though these vesicles are most highly fluid, nevertheless, through them, paths are laid down with the utmost distinctness, whereby the spirit flows most distinctly to its goals and its appointed ends; confer Transaction I., n. 313. These facts, however, do not prove that the tunics of the fascicles are double, but only that they may be double; still the similarity of the case in the glands,

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**i. e.,* for suffering action.

muscles, and other membranes of the body would seem to lessen the doubt though it does not remove it.

216. *That the tunic of the fascicles is double, is declared from its first cradles; for as soon as the fibre is born from the cortex it joins itself with its companion fibres, near by or far off, which are of the same office, and, then, like fascicles, they at once enter under a loose tunic, that is to say, a fascia and close web contextured of vascular offshoots. This web [surrounding] the fascicle discriminated into plexuses, is then continued through the whole medullary portion of the brain all the way to its boundary or meningeal surface; from this is drawn the first or inmost tunic which surrounds the fascicles and at the same time gathers together the scattered fibres. But when the fascicle thus introduced to its inmost or proximate tunic breaks out from the medullary stem of its brain, it covers and girds itself with the pia mater, and thus puts on a new and second tunic.* That the new-born fibres flow into a sheath compaginated of vascular offshoots, and this at a distance of hardly a few lines from their origin, see merely the plates of Bidloo, and Verheyen.* That the little vessels of the brain form tunics around the fascicles and plexuses of the fibres which constitute the medullary† brain, confer n. 128, 129, 196. From these and other considerations it may be concluded that there is nothing in brain and body which is not tunicated, that is to say, distinguished from its neighbors by tunics. Moreover, that the medullary fascicles before breaking through the pia mater and girding themselves with a second covering therefrom, are beset round about with a kind of tunicle, is apparent in the

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*Bidloo's plate is a view of a section of the cortex of the brain seen under the microscope. It shows a large number of cortical glands; below the mass of these glands a number of delicate lines representing fibres, are shown, which almost immediately come together to form about five or six fascicles or nerves. (*Anat. Hum. Corp.* Amster. 1685, plate x, fig. 2. The same figure is also shown in Cowper's plates.) Verheyen's figure is like Bidloo's—though smaller. (*Corp. Hum. Anat.* Amster. 1731, tab. 34, fig. 6.)

†The Latin here is *corticale* (cortical).

cauda equina, which is the last portion of the medulla spinalis; for the whole of this cauda is made up of fascicles and nervules. These fascicles, even before they have reached the pia mater, are nevertheless covered with a tunic which they must have received from the medulla itself. These proofs make it manifest that the fascicles also are involved in a double tunic.

217. *This pia mater is not a single membrane but a double, and, if we add the arachnoid, a triple. Hence it follows that the membrane which surrounds the nervules or fascicles, now become the beginnings of the nerves, is at least threefold.* That the pia mater is double, is asserted by some of the keenest investigators as a result of their experience; at any rate from its inner surface are put forth an infinite number of shoots, like fibrils, while its outer surface remains intact. Its inner surface, therefore, is rough and appears to be beset with some mucous fluid, while its outer surface is smooth and even. This argues that there is some duplicature. The same conclusion may be made from the arterial vessels which mark its outer surface. With respect to the arachnoid tunic, no doubt can be entertained but that it is extended through the whole of the pia meninx; but as to the mode in which this tunic also involves the fascicles,—this will be seen below.

218. *From the above it is also apparent that the nerves are productions and continuations of the brain; for they carry with them not only its fibres and vessels, that is to say, the medulla, but also the meninges themselves, and, moreover, all those spirits that have their origin in the cortical substance; and also all other humors secreted by the cortex, and which work their way through the sieves of the medullary substance and are derived into the nerves.* The vessels, as being more inert and reactive than the fibres, betake themselves to the surface, while the fibres, being active, betake themselves towards the axis, and to the centres. The humors springing from this living fountain, that is to say, from the brain, are derived into the interstices of the nerves. *Thus the whole brain is present in the body, but like the nerves, it is there parted and distinct, in exact ratio to the effects at the extremes.*

219. *The finest membrane, meninx or tender bark which in-*

vests the single fibres, that is, which constitutes the channelet itself, seems also to be a twinned membrane if not a triple. For the inmost tunic of the fascicles puts forth shoots which enter into the single fibres and bind them together. The same conclusion is also deducible from its first origin; for the fibre arises from its cortical gland from which it is drawn out by continuity, and that this gland is girt about by a most delicate and soft meninx, is confirmed, albeit obscurely, by experience. Moreover, each cortical spherule, is, in least effigy, a gland, heart, brain, muscle; that is to say, is everything which performs any manner of office in the body. See Transaction II., n. 176-202, and also n. 144 above. *This mater of utmost softness, cannot but be produced into the fibre which is a continuation of its cortex.* See Transaction II., n. 111, *seq. But the finely subtle fibrillar substance which forms the body of that gland, and which likewise is drawn around the fibre by continuity, is its inmost membrane and lies under the former.* Such an effect is an inevitable consequence of the connection and origin of the fibres from their cortical glands; for there is no room for doubting, still less for denying the fact that these glands are corpuscles of a spherical form approaching to the oval, and that a corpuscle of this kind is contextured of the most delicate threads, which constitute its highly subtle medullary substance. A fabric or minute medulla of such nature must by all means be terminated in some surface covered over with the softest meninx, wherein, namely, it places its limits, and whither it extends the sphere of its forces. Add to this, that if the fibre be the continuation and elongated appendix of its cortex, then this most pure fibrillar or medullary substance, together with its softest meninx, must be carried over into the fibre. From the genesis of the fibre thus confirmed, it follows, that the fibre also is furnished with a double tunic.

220. *Thus the mode in which the nerves are tunicated, that is, are limited by tunics, is apparent; for it is fibres that constitute the medullary substance of each nerve, and vessels, or arterial and venous terminations, that constitute their tunics.* See above, n. 144, 165, 166. *The fibres are most highly active since they are the forces of the brain and body; while the ves-*

sels whereof the tunics are made up, are passive, and relatively, are inert forces. See above, n. 138, 139, 140, 164. *Thus to the nerves are given forces of a diverse disposition, to the end that there may be those that act and those that react, that is to say, that temper, limit and restrain the activities of the fibres; and this in such order that the impulses from the centres to the surfaces may decrease by their degrees. Such is the sphere and limitation of the activity of fibres, fascicles and nerves.* To the above it may be added, that the vessels of the brain, which, relatively to the fibres, are passive, or, what amounts to the same thing, reactive, become still more inert as they progress, so that in their ultimate ramifications they lose almost the whole of their reactive nature. For the origin of their motion is in the brain, and depends on the general animation of the cortex; therefore they go off into stems that are entirely dead and are gifted with no power of reaction; for nothing of the vital juice flows into them from any fountain, as into the genuine fibres, and the only thing that produces fluidity is that vital essence which is conceived in the cortical glands and is continually excluded by them. In order that nature may supply this defect new vessels enter into these tunics in the body, and also into the nerves.

221. *There are ligaments which connect the several fascicles with each other, and the several fibres with each other, and also the nerves with the fascicles and the fascicles with the fibres, and bind them together to act as one. These ligaments, bonds or fetters, untied and plucked, as it were, from the inner layer of the tunic of some nerve, penetrate towards the interiors of the nerve and flow into the outmost tunic of an enclosed fascicle; and on the way they so ramify, that they bind the several fascicles together. So likewise there are ligaments extending from the inmost tunic of the fascicle to the outmost tunic of some fibre,—the case being not unlike what is seen in the brains, tendons and muscles.* Authors make mention of having frequently observed this phenomenon in the nerves, and it is visible also in other compositions.

222. *These ligaments in the nerves are not continuous webs* *or membranes; but they are discreted propagations and offshoots which form septa and cellules between the fascicles and between the fibres,—and this with such contrivance and direction that the humor circulates freely around every fascicle, and around every fibre, solicitously guarding against their growing together, and enabling them to keep their natural state and mutual situation and to be brought back thereto as often as any change is induced upon them.* That this is what obtains in the tendons, has been set forth by Leeuwenhoek who has observed it: "I recently found (says he), that not only are tendons invested by a strong membrane, but that this membrane gives rise to little branches, and that these, luxuriating into new branches, form septa which again are dispersed into lesser tendons." (n. 41; see especially fig. 16.) That a large quantity of fat was found between the fascicles of the nerve, see fig. 2, and n. 206; that this fat is held in the cellules, is well known. The same is confirmed *a priori* or from principles. For unless the humor permeating the interstices of the nerves were frequently intercepted, it would be expelled out of doors and be dissipated at the first expansion of the fibre or fascicle, and thus would not be determined to the use intended by the brain in the fibre; thus, with the flying away of the interstitial fluid the state of the fibre or fascicle would fail to be restored, and fibre would coalesce with fibre and fascicle with fascicle. Therefore, care seems to be taken that this circumfluent humor, which likewise is reactive, and, relatively to the animal spirit enclosed in the fibre, is passive, shall press upon every point of the convex surface, just as the enclosed humor presses upon every point of the concave surface. We can make a rough experiment of this if we try to break a nerve by pulling it lengthwise or in the direction of the flow of its fascicles; the ligaments then cause a certain delay in the breakage, a number of them unfolding from the inner parts of the cord; and this cohesion is sufficient argument for the colligations spoken of above.

223. *For fibres, which are the active forces of the brain and body, are continually endeavoring to induce change, but are as often restrained by circumfluent juices and tunics, lest they carry themselves beyond limits and the sphere of limits.* According to the general rule that every active force tends to a change of its own state, that is, of the state of the substance wherein it is; nay, it would produce such change were it not restrained by the contiguous parts. Hence is deduced the cause of all equilibrium in the things of nature, and of the loss thereof.

224. *From the duplicatures of the tunics we can also gather, that some lymph of an oily nature, or some subtle moisture flows between them, which anoints the points of juncture, and guards against their coalition. Thus, in a cross-section of the nerves, there are seen other little passages and open commissures, not hitherto mentioned. Therefore it is clearly evident that in the nerves there is nothing that is not transpirable and perspirable.* According to the teaching of Hippocrates.

225. *When these bonds are too greatly constricted, fibre coalesces with fibre and fascicle with fascicle, and the tunics stand open.* For since the inner tunic of the nerve is colligated with the outer tunic of the fascicle, therefore, when the copulas or bonds between them become constricted, the duplicatures necessarily open out and amplify; for the bonds bring the tunic of the fascicle nearer to the tunic of the nerve. *Thus the permeability is lost, and the nerve refuses to admit the juice of its brain. Hence comes lack of response, impotence of action and sensation, rigidity, fragility, old age, and finally death.* Thus according as the structure of the nerves is more agreeable to the laws of nature, so it is the more transpirable, and also perspirable, the more potent of action, and the more youthful and vivacious.

226. *On the other hand, when the bonds are too greatly relaxed, or are ruptured, they betake themselves back to their tunics, and then fibre is disjoined from fibre and fascicle from fascicle, and the tunics are agglutinated together; hence an abundance of unordered humor flows in and stops up the interstices with serums, phlegms and fat; whence come various kinds of diseases both of the head and of the body.* Of these we shall speak below.

227. *For the interposed ligaments together with the tunics and their duplicatures enable each fibre and each fascicle of fibres to enjoy its own proper sphere of activity, within which it acts in the greatest freedom, though under the restriction of the law that, while it breathes its own good, it must also breathe the good of the community.* That the fibre can act by itself, and the fascicle by itself, is a consequence following from the mechanism of the duplicature of the tunics, that is to say, from the fact that the outmost tunic of the fibre is connected with the inmost tunic of the fascicle, and the outmost of the fascicle with the inmost of the nerve. The effect of the space between the tunics is, that they do not depend on the neighboring parts except so far as a similar and thus a common action is enjoined on them both by the brain. But because the outer tunic can recede from the inner no farther than is permitted by the neighboring parts, and, it may be, by the tiny ligating cords which pass between them, so each fibre, or each fascicle, must stand for the common good while it is standing for itself or for its own good. For the most perfect life consists in this,—that all the parts live a common life, but, at the same time, that all the least individuals, each furnished with its own force of action, conspire to unanimity; and therefore over them all stands one queen,—the soul. *Thus here, as in all other places in the animal kingdom, is represented the entire form and state of a society and republic. For when these bonds are loosened the communion is destroyed, and each fibre works for its own cause, and each fascicle for its; and then the brothers, disjoined from each other, easily become discordant, yea, and rebellious; hence the State is overthrown, and the Kingdom dissolved. This is the sole cause of old age and of death, after the Fall. For as often as the pleasures of the body and the affections of the animus make war with the desires of the ends of the mind, so often are the beginnings of the fibres, which lie in the brains, made to suffer, and the ligatures everywhere either relaxed or constricted; and straightway too much or too little of humor is transmitted; the ani-*

mal spirit also and the blood are disturbed, and admit unsuitable elements whereby they are defiled. Thus it is nothing else than the intrinsic discord between the forces and the subject parts in ourselves that hastens our years into old age, and this into death,—just as in societies, kingdoms and great empires.

CHAPTER XII.

THE CONJUNCTIONS AND PLEXUSES OF FIBRES, FASCICLES AND NERVES IN BRAIN AND BODY.

228. *In the organic body are the most wonderful anastomoses and intertwinings of fibres, fascicles, and nerves, so that the organic body is as it were a perpetual plexus made up of an infinite number of minute plexuses. It is the fibre that spontaneously flows into such plexuses in the brains; the fascicles of fibres, outside the brain but within the cranium and the vertebral sheath; and the nerves, in the body. But the nerves again split up into fascicles, and these into fibres, and these go off into reticular plexuses, webs, and organic forms, which correspond to the plexuses in the brains, as an effect to its causes and causes to their principles.* But let us take up these points one by one.

229. *As regards the* Fibres: *These straightway intertwine and connect with each other, as though they feared to progress far from their origin alone. They mutually consociate as it were into fascicles, and commit and pour themselves into some sheath which likewise is a mesh made up of vascular ramifications. Thence they proceed after the manner of fascicles; frequently also they split up into plexuses, which yet are coherent with each other; that is to say, one is continued into another, not unlike what obtains in a spongy structure. For from its universal cortical circuit, both anterior and posterior, nay, from its penetralia, glands, tubercles, and ventricles, the cerebrum sends out fibres which come together in the medullary globe or centrum ovale. Thus fibre runs along with fibre, and fascicle with fascicle; and they intertwine with* *each other, and then recede and unfold. Hence arise anastomoses and plexuses. Who can guess the manner or the frequency with which the fibres mutually consociate? or the origin of the gathered fibres? whether they come from different hemispheres? from the base of the brain, or from its vertex? from its margins or from its medullas? or whether, simultaneously, they come from the corpora striata, which likewise put forth an abundance of fibre, and distribute it round about? But to resume: There arise as many nodes and mattings as there are plexuses, whence arises a common node contextured of least nodes, and irresolvable.* As regards the fibres of the corpora striata they seem to be intertwined with the fibres of the cerebrum round about, and especially to be woven in with those that go down into the medulla oblongata on its anterior part. This may be confirmed by many particulars. *Anyone who is acquainted with the figure of the cerebrum, and with its division into tuberosities and ventricles, will acknowledge the circumflexions and windings of its fibres and the intertwinings arising therefrom. *But although it proceeds by windings, yet each fibre tends to its companion fibres by the shortest path, and seeks out these companions, wheresoever they be, and foregathers with them.*

230. *Again, the fibre of the cerebrum which is carried down into the medulla oblongata, joins itself with the fibre of the cerebellum in the annular protuberance and in the neighborhood of the fourth ventricle, and the two are wonderfully entwined with each other. Thus, the medulla oblongata reduces those great and living twin globes, the cerebrum and cerebellum, into concord and association of office and motion.* See above, n. 98.

231. *Moreover, this fibre goes down into the medulla spinalis, and binds and decussates with all the fibres that spring from its axis. For the fibres of the cerebrum and cerebellum run down the spine in the direction of its length, while the fibres proper to this axis run out perpendicularly, obliquely, and spirally. Thus the one fibre necessarily touches, crosses, and binds down the other; nay, very frequently the fibre of*

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*In the Latin the italics begin here.

one side crosses over to the other side. Hence results such a matting together that the spinal fibres depend on the fibres of the head, and all on the fibres of the cerebrum, and they are so bound together that not one of them is capable of doing anything for itself, unless at the same time it acts for the common weal. Moreover, as a further result, the structure is the more firm and the more protected, the more it is stretched, and exercised, that is, the more readily it is excited into natural motions. For this reason the whole medulla of the encephalon is one continuous plexus and one inextricable node, wherein is not a thread which is entirely of its own jurisdiction unless at the same time it be under the jurisdiction of another and of all. Who then would surmise other than that there is not a single nerve nor the beginning of a nerve which does not derive something of its origin or something of its nature from both brains and at the same time from both their medullas? This is openly supported by Boerhaave; see above, n. 45, 46, 47, [48].

232. *As regards the* FASCICLES *of fibres: Issuing from the medullary stem singly and in scattered order, they mutually unite into bundles which finally become nerves under a common tunic, that is, under the dura mater. It is well worthy of note that one fascicle,—now called the beginning of a nerve,—searches for another and seeks it out with such foresight and keenness of vision, that it bends around in circuits, spires, and windings, now bearing downwards and now upwards (as for instance, from the cervical spine through the great foramen of the occiput* [n. 117]*); and on the way, it climbs over many other fascicles and passes them by, as though it knew the ones with which it was about to live in society as fellow-consorts in the same office, what their quality, and where they were to be found. Thus each single fibre foresees all that it is about to do in the extremities; and it holds this steadily before its sight as though itself were present in the effects, even while it is in its principles, causes, and naked potency.* Confer Trans. I. n. 260-269.

233. *Finally, as regards the* NERVES: *These form anastomoses and plexuses in the body in almost the same way as* *the fibres do in the brain; and this for the sake of a continuity of cause; namely, lest the marriages of the fibres, happily entered into in the brain, be broken up by the divorces of the nerves in the body; and, on the other hand, that these marriages may be reintegrated by new conjunctions. For as soon as the nerves, after piercing the cranium and the vertebral bone, penetrate separately into the kingdom of the body, then, like brothers come forth from the womb of one mother and who are still nourished by her twin breasts, they rush, one into the bosom and embrace of the other; they come together in a body and tunics; they again separate; then return and renew their loves; and so on, from time to time, as though they would enter into counsel as to what they should do, and would mutually exhort each other to stand in concord, despite the departure of each of them to his own assigned province, that is to say, to a muscle, an organ, or a gland. Thus the ultimate fibre of the spine again commingles with the highest fibre of the head, and the next following fibres with the mediate; and they carry out in the body those connections which they had set out to accomplish while they were still in the brain. But to expound the several modes and numbers of these interweavings, and to enter into their ratio, is a work of many ages, of many men of genius and of many pages.*

234. *Moreover, there are in the body many reticular* PLEXUSES: *namely, the two pulmonary plexuses, the two cardiac,—the greater and the lesser,—the stomachic, or rather the coronary, the three mesenteric, the splenic plexus, the hepatic, and the two renal plexuses,*[*] *not to mention entire fascias or bonds which are in like manner plexiform. For sometimes the nerves or a single larger nerve is broken up into lesser nerves, and these connect and knot with each other at little distances, thereby producing quadrangular or polygonal areas after the manner of a fishing net. For a larger trunk, wherein*

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[*] The plexuses here mentioned all belong to the sympathetic system. In modern terminology, they are: The anterior and posterior pulmonary; the deep and superficial cardiac; the gastric, or coronarius ventriculi; the superior and inferior mesenteric and the aortic; the splenic; the hepatic; and the renal and suprarenal.

a number of fibres and fascicles are compacted and bound together by bonds, seems to enjoy a freer flow when it is split up into finer, and at the same time softer [nerves and fibres], for it then transmits its spirits and humors with greater expedition, and, in the extremities where they are finally distributed, it exercises its forces with greater certainty.

235. *There are moreover similar plexuses of fascicles and fibres in the sensory and motory organs, as in the tongue, the eye, the ears, the cuticles, and in the several membranes and muscles. For the organic parts of the body are so many webs and plexuses of fibres and vessels, it being merely their form that makes the effects to be such as are presented to view.* For since the fibres are so many forces, and since no fibre, and hence no force, is absolutely like another, therefore, from the coalescence and tempering of such fibres and forces, there is produced in the extremities a form which is called organic, and from the actuation of which, results that effect which is represented as form in the idea* of the mind. By reflection we notice this in our own persons; and we have also the testimony of experience in the observations made upon the bodies of embryos; see Trans. I. n. 267.

236. *Each single nerve is one series and signifies some general action, either simultaneous or successive, because it produces such action. For action belongs to the muscles, and these owe their faculty of action to the nerves; the nerves to the brains; the brains to the cortical substances, and these to the soul. Thus, by means of cortical substances, fibres, nerves, and muscles, the soul produces that action, of which itself cherishes the idea. Fibres, therefore, are, as it were, the rays of its intellectual light, whereby that is represented to it as present, which in actuality, is distant. Every single action, whether simple or compound, is the joint product of forces of divers qualities and quantities, that is to say, of divers natures; consequently of divers origins. In order therefore, for*

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*It may be noted that the word *Idea,* derived from a Greek word meaning "to see," signifies a picturing imagination, representation in intellectual mind. In the classics the word is used in the sense of architype, and this meaning is also clearly included in our author's use of the word.

the existence of an action conforming with the idea represented, the fibre is collected from divers points of the encephalon. This is the reason for the so numerous anastomoses and plexuses, both in the region of forces, that is, in the brain, and in the region of actions, that is, in the body.

CHAPTER XIII.

THE GANGLIA OF THE NERVES.

237. *The nerve, especially the intercostal, sometimes tumesces. These tumescences are called ganglia, ganglions, gangliform plexuses, nodes, tumors, and olivary bodies of the nerves. For the most part they are of an oval shape furnished with tendinous extremities, that is, with head and tail, just like the muscles. They are larger, as for instance the semilunar ganglia; and smaller, as for instance the barley-shaped ganglia of the spinal nerves. They vary in consistency, color, volume, and number. While arising from the combination of a number of nerves, they are for the most part implanted in the trunk of some one. They are contextures and meshes of arteries, veins, and fibres,—nervous, fleshy, and tendinous,—and also of a number of membranes.* According to the searching investigations of Lancisi, whose entire description has been premised above, n. 16, for the purpose of this chapter,* the superior cervical ganglion of the left side is enclosed in three membranes which are slightly increased and thickened by the accession of fibres. The outer of these membranes invests the ganglion loosely, like the tunica vaginalis invests the testes, and by compression of the fingers the enclosed body can be pressed out like a kernel. On the outer side it is woven of reddish fibres; and on the inner side it is lubricous, being moistened by a mild humor like that of the pericardium. The second tunic, which invests the ganglion somewhat closely, consists of tendinous fibres which are more complicated and coherent with each other. The third tunic, which Lancisi calls the circular tendon, consists of a tendinous substance firmly united to the body of the ganglion, its fibres being contiguous to the fleshy fibres. In the ganglion when boiled and divested of its tunics, he found on the outer surface a kind of nervous network tenaciously entwined in its membranes. Under this network, and arranged in beautiful order, are seen fleshy fibres extending from the vertex to the lowest point. Moreover, emerging from the intermediate commissures of these fibres, are found innumerable fibrils which are joined to the inner tunic. The upper vertex of the ganglion, commonly called the punctum immobile, is attached to the bony fulcrums of the vertebræ and cranium by nerves and membranes. Into this cervical ganglion, just as into other ganglia, are admitted not one, but many nerves; of these, some penetrate the ganglion directly from above, some transversely to the belly and sides, and some obliquely. Most of them go to the internal substance of the ganglion, but some are dispersed through the membranes only. Those that go to the internal substance, appear to be slightly tinged with a sanguineous color, while the others are white. The blood supplied to the ganglia comes from the neighboring arterial and venous trunks; and this, together with the medley of nerves, constitutes a mass, which nevertheless always appears larger than its ingredient bodies and vessels would seem able by themselves to form.

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*In the Latin the rest of this paragraph is printed in italics.

238. *From the anatomy of this ganglion we learn the offices of the other ganglia. For the fibres of the nerves lie so compacted within their tunics, and the fascicles of fibres within theirs, that unless they be unfolded and loosened on the way, it would be impossible for them to pour forth their liquid in that abundance, which the viscera, by reason of their exceeding activity, continually and urgently demand; for in order that the latter may live in the performance of their work, they demand a continuous stream, and one that is nowhere checked. Therefore, in these ganglia, the nerves loosen up their beds, and being thus gifted with freer expansion, propel their fluid onwards. For the ganglions are muscular, being furnished with similar membranes, fleshy fibres, tendinous extremities, belly,* *and longish figure* [*as the muscles*]*; so that when they contract they draw up the continuations of the nerves, and when they unfold they relax the nerves; and they do this distinctly to the whole nerve, distinctly to the beginning of the nerve, and distinctly to the fibres of the fascicle.*

239. *Thus the ganglia, which are the vehicles for the fluid of the nerves, may be called little succenturiate brains, and at the same time aids to the lungs in the promotion and transfusion of the nervous juice throughout the whole kingdom. For the ganglia are attached to the vertebræ as to bony fulcrums which are vibrated and moved at every turn of the pulmonary respiration; consequently the appended ganglia are likewise excited to their contractions and expansions, and by these movements the nerves also are drawn up or stretched out, and the nervous juice forwarded through them in a wonderful way.* In Trans. II., Chap. i [On the Motion of the Brain], and also in Chap. ii, n. 172-175, I have endeavored to show that the lungs breathe and animate synchronously with the brains, and this for the reason that the spirit may thereby be more expeditiously promoted through the fibres, and the juice through the fistular structure of the nerves. For the brains inspire the single fibres, that is to say, they excite them severally to action; and at the same moments, the lungs either stretch or draw up the fascicles of fibres. Thus the lungs add to the fibres an external and general force, while the brains inspire into them an internal and particular force. For each single fibre, when swollen and filled with spirit, contracts from its former longitudinal extension, and becomes a shorter canal; since, however, the action is a general one, this is not easily accomplished without an external or pulmonic aid whereby the nerve is relaxed simultaneously. As to the mode in which the lungs concur to the transfusion of the nervous juice throughout the body, this is done with manifold skill. But a recountal of the several modes does not belong to this place. Let us therefore keep to the subject of the ganglia. For the most part these are set near the vertebræ and affixed thereto,—like the barley-shaped ganglia of the spinal nerves, and the semi-lunar ganglia of the intercostal nerve; and therefore, when the brain and the medulla spinalis act upon the fibres, the lungs at the same time, by their expansion and contraction, act upon the vertebral column and inflect or twist it. The ganglia which lie at the junction of the vertebræ, together with the fibres attracted to them, cannot but be excited into a similar motion, whereby the nerve proceeding from them is either relaxed or extended. See the whole mechanism explained above in Trans. II., n. 32, 33.

240. *Moreover, the ganglia also effect an entire change on the nerves that flow in, in respect to their surface, tunic, and medulla; and they instruct and reform them according to every use and series of actions in their extremities. For the nerves that come forth from the ganglia seem therein to have laid aside their old tunic, that is, the dura mater, and to have acquired a new one; for they come forth clothed with a tunic which is either muscular, or nervous, or tendinous. The dura mater cannot perpetually or for any long time act as a tunic around the nerves, since it is made up of vessels,—both its own vessels and those reflected from the body and changed over into tendinous filaments; and by degrees, as these vessels are ramified and recede further away from the origin of their motion, that is, from the heart and brain, they become finer and at last vanish.* This is contrary to the opinion of Baglivi, [*De Fibra Motrice,* Chap. v], who holds that the dura mater is not only the principal cause of the motion of the heart, but is also the origin of its fibres, in that the one position follows from the other. For in order that the dura mater may incite the muscle of the heart to the execution of its alternations, it is necessary that a fibre spring forth therefrom, which shall actuate the motor fibre, or shall act upon the motor fibres. That the dura mater, however, is not continued entire around the nerves beyond the ganglia, is clear from the description of the latter. For the outmost and inmost tunics of the ganglia are perforated by fascicles and by great numbers of gathered fibres; and the fibres themselves, both the genuine and the sanguineo-motory, enter deeply into these tunics and interpose themselves between them. This is exhibited still more conspicuously in the outgoing nerves; for among these are seen nerves whose tunics are white, somewhat hard, and tendinous, others whose tunics are sanguineous and muscular, and others with nervous and active tunics. Thus the old meningeal tunic is most certainly reformed into a new and different tunic. Add to this that innumerable vessels penetrate the structure of the nerves, and if, according to the theory of the preceding chapters, the office of these vessels be the weaving of tunics, here certainly, their office should be the restoring of tunics,—a work which the fibres themselves cannot do, inasmuch as they are not ramified like vessels. That the dura mater is contextured of vessels and not of fibres, cannot indeed be demonstrated in a few words, but it comes for demonstration in the Transaction on the Dura Mater.* For the present we merely remark that this gross meninx consists of a two-fold layer, and that its threads are of a tendinous nature and therefore ligamentary, being by some anatomists called muscular. In this matter, all anatomical investigators are in agreement; that is to say, that the nature of these threads is like that which is usually taken on by vessels when deprived of their blood, as for instance the umbilical and other vessels. This can also be confirmed by the fact that the dura mater in the infant is irrigated by an immense number of vessels which afterwards become tendinous; and by the further fact that the dura mater is a somewhat passive, resistant, and gross membrane, being furnished with no self-power of action. Then again, these vascular cords which have become tendinous, are continued from the corporeal vessels by some path thus far unknown,—of which we shall treat in the above mentioned Transaction. The arteries of the dura mater, from which it derives the principal part of its activity, run between its two layers, and, by continual ramification, finally become exsanguineous; so likewise these vessels when the dura mater is continued over the nerves. The arteries of the dura mater depend in particular on the expansion and constriction of the heart, and in general on the expansion and constriction of the brain, thus on a two-fold origin of motion, as may be seen in Transaction II., Chap.

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*Cf. n. 168, and see the BRAIN, n. 198, seq., particularly n. 202, 257, 286a *seq.*

i, § 10, [n. 55 *seq.*]. Therefore, in proportion as they recede further away from these origins of motion, so must they be gradually rendered finer, and at last pass off into secretory tubules,—as is the case with the arteries in all parts of the body. Therefore the dura mater is not continued around the nerves, but is reformed in the body, and indeed in various ways, according to every ratio of actions in the extremes; of which actions, one demands a nerve furnished with a muscular tunic, and another, a nerve furnished with a tendinous tunic; for in the whole animal microcosm there is not a single nerve that is tunicated exactly like another. *But the tunics, not only of the nerves but also of the fascicles, seem to be renovated. For the arterial and venous vessels of the body enter into and penetrate the nervous trunks, and flow longitudinally with the fascicles and fibres, and also bisect the nervous structure both obliquely and transversely.* That in the structure of nerves are found many arteries and veins which continually split up into branches and frequently perforate the nerve transversely, is often mentioned by Leeuwenhoek in the observations premised to this Transaction. These vessels can perform no other use than the restoring of the antiquated and disappearing tunics; for the fact that tunics are made up of vessels and threads of a passive character, has been pointed out above; and also that they secrete a juice and pour it in between the fascicles, and perhaps also between the interstices of the fibres lest these grow together and lest the glands be deprived of their fluids from which are prepared menstrua and animal juices of every kind. *It was also observed above that bloodvessels are of a passive nature respectively to fibres, which are most highly active; and that vessels form tunics and at the same time ligaments; also that vessels ramify, but not fibres; from all which it follows, that, in respect to their tunic, the nerves must be reformed in the body in order that a due ratio may be preserved between their action and reaction all the way to the end of their extension, that is to say, to the effect in their extremities.*

CHAPTER XIV.

THE VARIETY OF FIBRES, FASCICLES, AND NERVES.

241. *No fibre, no fascicle of fibres, and no nerve is absolutely like another, but is varied both in species and in part. The fibre which is born of the cerebrum is of one quality, that which is born of the cerebellum of another, and that which is born of the medulla oblongata and medulla spinalis, of still another. Yea, neither do the fibres of the cerebrum agree with each other in all their predicates,—there being differences between each one of them. So likewise between the several fibres of the cerebellum, and between those of the [medulla oblongata and] medulla spinalis. For between the cortical glands which are the genitors and nurses of the fibres, there is a perpetual variety which we call an harmonious variety. Hence a like variety is passed on to the offspring, that is, to the fibres; for the fibre inherits the nature of its parent gland. Every fibre is begotten and moulded, yea, and bent, to some use in its extremities; and in every part of the corporeal system the use is varied. Wherefore the fibre derived to the motory organs, is of one nature, and that derived to the sensory organs, of another; that is to say, one kind of fibre is derived to the eyes, another to the ears, another to the tongue, nostrils, cuticles, another to the trachea, another to the stomach, intestines, lungs, heart, mediastinum, liver, pancreas, spleen, loins, soles, elbows, palms, and, in fact, a different kind of fibre to every least portion of these parts. Hence also it follows that each single fascicle composed of fibres of such diverse nature, and likewise each single nerve, has a specific difference from other fascicles and nerves. Effects in the extremities correspond to causes in the beginnings; thus organic parts in the body to organic parts in the brains. Hence comes the variety of the fibres, which are intermediaries and accommodate themselves to both ends. The variety which obtains in the several entities of all the kingdoms of the world, the animal, vegetable and mineral, yea, and in the circumfluent or atmospheric world, is* *a necessary quality or attribute of universal nature, which is averse to all equality and identity, shrinking therefrom as from something destructive of herself; for without variety, there exists in nature, neither thing nor quality. Hence come the relations, respects, ratios, harmonies, equilibriums, forms, and beauties of the things of nature; in a word, their perfections, if the variety be harmonious, and contrariwise, if it be inharmonious.* Respecting this variety see Trans. I., n. 602, 603, 604, 605, and Trans. II., n. 312-316. Wolff is of the same mind; for he says "That world is more perfect wherein is a greater variety of things consentient. For if, in a world, the variety of things which are mutually consentient is greater, then more things would be observable in that world than in a world where the variety was less. And therefore, since that world is more perfect wherein is a greater number of things observable, it certainly follows, that that world is more perfect wherein is a greater variety of things consentient" (*Cosmologia*, § 552). *The superior and more perfect entities of nature excel over other entities in the fact that they are more susceptible of variety, and hence are more apt for an accidental change of their state, but not for an essential change. Hence comes the perfection of forces and modifications, and their potentiality of being the causes of infinite varieties in things posterior. But this accidental change derogates and takes away nothing from the essence and the attributes thereof. Wherefore this most perfect mutability possessed by superior entities goes ever hand in hand with a most perfect constancy in ever remaining in their own form and essence.* But the question is asked, What is an accidental change, and what an essential? Let us learn by examples. A circle or a spherical globe suffers accidental change when it is expanded into a larger circle or sphere, or compressed into a smaller; for the circular or spherical form, that is to say, its essence, still remains. But if the circle is changed into an ellipse or cycloid, and still more if it is changed to some polygonal and angular figure, then it undergoes an essential change, for it no longer remains a circle. So also in other things, as in the atmospheres and the parts thereof, which, howsoever expanded or constricted, suffer none but accidental changes; but if they change their form, they change also their essence, and then these parts no longer remain atmospheric, modifiable, and elastic. A muscle when it contracts and dilates undergoes none but accidental change,—and so with the brain, heart, lungs, when they perform their systoles and diastoles; for whether they be more ample or more constricted, they are still muscles, brains, heart, lungs,—which would not be the case if they were changed essentially. The cortical gland undergoes accidental change at every alternation of its animation, and also according to the several modes of sensation,—for the cortical cerebrum is the common sensory; but if it can no longer be expanded and constricted, that is, can no longer draw its breath nor any longer receive sensations, then in that degree it is said to undergo an essential change. So likewise the fibres, in that they are minute canals, which, whether wide or narrow, long or short, nevertheless remain fibres; for these varieties arise from some accidental change, nor do they derogate anything from the essence and natural form of the fibres; nay, the latter are the more perfect, the more readily they are able to undergo these changes, that is, the more tender and soft they are. Thus there are no elastic corpuscles which do not yield at the least attacking force, and then straightway return to their own state; thus they react, altogether as they are acted upon, but do not readily undergo essential change. Such are the entities of superior nature, that is to say, primitive entities.

242. *And now to enumerate the varieties themselves:* FIBRES *are in general, more or less soft or hard, ample or narrow, to say nothing of their being long or short.* This is evident from the very anatomy of the fibres in the brains. For the fibres that go to the organs of the senses are softer, and those that go to the muscles are harder; wherefore the former are called sensory nerves, and the latter motory nerves. The nerves of the fifth* and seventh pair† consist of both kinds, as also is the case with several other nerves, according to the observations of Ridley [n. 18 *fin.*]. Sensation requires a more tender consistency in the nerve, but motion a harder; for the effect and use in the extremities corresponds to the causes, and, if I may so speak, to the intuition of ends, in the beginnings. Thus the fibre, which acts as the middle cause, is accommodated equally to both ends. *Their tunicles or meninges likewise,—these being either tender or gross, and cohering either loosely or strictly. The animal spirit itself, which flows through the fibres, is never absolutely the same in the fibre of one subject as in that of another, as will appear from the genesis of this spirit as shown in the following Transaction;* and according as is the fluid which flows through a fibre, such also is its tunicle, for the one has been and is accommodated to the other.* For, as the tunic of the artery is formed to the nature of its blood, so [the tunicle or] highly delicate surface of the fibre is formed to the nature of its fluid. Thus the tunic and its enclosed fluid constitute one vessel, and act as a single cause; see above, n. 151, 152, and Trans. I., n. 134, 135. If therefore the humor is everywhere varied, the fibre also must be varied. *So likewise that chastened humor which permeates the interstices of the fibre.* Respecting this humor see above, n. 192, 194, 197, etc. *Fibres, therefore, transmit a better or a meaner juice or spirit, and this either quickly or slowly, and in abundance or sparingly. But to resume: The softer the fibres and the more nearly they approach to the nature of a fluid, the more susceptible are they to accidental change, which is their protection, and the more apt for acting according to their nature. In first infancy, and also near their*

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*Now called the trigeminal.

†The hard portion of this nerve is now called the facial nerve, and the soft portion the auditory.

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*See the little work on the ANIMAL SPIRIT (in Posthumous Tracts), particularly chapter iii. It would appear from this reference to "the following Transaction" as treating of the Animal Spirit, that the present work was written after the plan of the ANIMAL KINGDOM had been formulated. For in all the sketches of the contents of the six Transactions that were to constitute the ECONOMY OF THE ANIMAL KINGDOM, no mention is made of a separate treatise on the Animal Spirit; but in the prospectus published in the first volume of the ANIMAL KINGDOM, we find that Part ix was to deal with "The Cortical and Medullary Substance; the Nervous Fibre; the Motor Fbre; the Animal Spirit."

origin, they are most exceeding soft and open, but in the decline of age, and at a distance from their origin, they are harder and more constricted. These varieties are indeed few, but inasmuch as the degrees of expansion and constriction, and of softness and hardness, are almost infinite in these least substances of animal nature, therefore the varieties cannot be limited by number. For one degree in things compound embraces myriads of such degrees in things more simple. Confer Trans. I., n. 290. It should be known that the differences of varieties in more simple substances are fewer in number because such substances are more universal; wherefore they do not admit of specific differences except such as, relatively to compound or posterior substances, must be called generic. But as to the manner in which such more simple substances are susceptible of infinite accidental changes, see Trans. I., n. 602-606, and Trans. II., n. 312-316.

243. FASCICLES, *which are nothing but aggregations of fibres of this kind, derive their nature from their constituent fibres; as, that they are more or less soft or hard, ample or constricted, long or short. But in fascicles many accidents are added, which are extrinsic to the fibres, but intrinsic to the fascicles.* Such for instance as the number, size, figure, situation, space, etc., of the fibres,—all which are accidents whereof the essence of the compound entity consists. But in order to the existence of accidents, substances are required, which, inasmuch as they constitute a compound, must be called simple substances. Assuming then that the fibres which compose the fascicle, are such substances, it follows, according to the rules laid down by Wolff in his ONTOLOGY, that "Compound entities are the aggregates of substances" § 793. That "Accidents cannot exist without substances" § 791. That "The essence of a compound ens consists of nothing but mere accidents" § 789. And that "In a compound ens there is nothing substantial except the simple entities" § 792. And although the fibres in fascicles are not truly simple entities such as are referred to by the distinguished philosopher, yet they here represent such simple entities inasmuch as they are the most simple parts that are visible. Nevertheless the fibre consists of its own constituent substances which are still more simple and in respect to which the fibre is a compound entity; and these substances again consist of their constituent substances and at last of the most simple substances of nature, that is, the first substances of the created world. Such substances, however, cannot be said to proximately compose a fascicle of fibres, but only most remotely, and indeed by means of many degrees. Therefore, accidents are here predicated only of such substances as enter into and form the compound immediately; as, in the present case, the number of the fibres, and the resultant size and situation of the fascicle, whence come the form and figure both of the whole fascicle and of the interstices between the fibres. And in order that it may be held in its natural situation there is required a nexus and ligation; and moreover, a surface which shall so limit the compound that while the fascicle is preserving its essence and determination, each single fibre does the same thing. *Fascicles therefore are made up of many fibres or of few,—consisting either of some hundreds, or of fives, or of pairs; they are made up also of fibres of different natures, and at the same time of arterial and venous vessels and of a greater or less abundance of such vessels. The tunics of the fascicles are more or less coarse or fine, hard or soft, and more or less elastic, active, muscular, sanguineous, fibrous, tendinous, passive, friable, and inter-coherent, since they are triple membranes. So likewise the very ligaments which penetrate from the inmost tunic of the fascicle to the outmost tunic of each fibre.* See above, n. 221. *For these ligaments are more or less dense or open, continuous or discrete, few or many, yielding or rigid, elastic and active or resistent and passive; and they interpose themselves and colligate the fibres more or less tightly or loosely. The interstices in and between the several fascicles and fibres are varied in like manner. The serous humor which permeates the interstices is never absolutely the same in one subject, or in the nerve of one subject, as in another; for it is more or less tenacious or fluid, fatty or watery, impregnated with homogeneous or heterogeneous elements, abundant or sparse, cold or hot, heavy or light; and so likewise with that oleaginous fluid which flows down between the tunics.*

244. *Similar and still greater varieties occur in the* Nerves. *For all differences pertaining to the fibres produce variety in the fascicle, and all differences pertaining to the fascicles produce variety in the nerve, which is an aggregate of fascicles. There are now added varieties which are proper to the nerve itself, arising from the situation, nexus, size, and number of the fascicles, and also from the common tunic; which varieties are again as many as those recounted above in speaking of the fascicles. To these are added varieties of anastomoses, and of plexuses, reticular and gangliform. The number of the varieties is inexpressible; for it arises from every variety peculiar to the nerve, traced back to every variety peculiar to the fascicle, and this traced back to every variety peculiar to the fibre. And therefore, since there is so great variety in the nerves, so great in the fascicles and also in the fibres, there certainly results from the continual multiplication of these varieties, a quantity that is unassignable.* Here we find something similar to what occurs in geometrical series, as when we wish to find out in how many ways the letters of a given word, or the numbers in a given sum, can be transposed. *But the varieties in compound entities, and, in the present case, the varieties in the nerves, are such that they can hardly be compared with the varieties in more simple entities. For each variety has its maximum and minimum. In compound entities, the degrees of varieties between the maximum and the minimum are fewer, and more slow, and uneven; but in simple entities they are more numerous, quick, and even or similar, and thus more harmonious and consentient, for they are applicable to each least moment or minute of mutation. Compound entities therefore, and, in the present case, the nerves, are more imperfect and more liable to essential changes whence arises destruction; and unless they were constantly determined by simple entities, and brought back and restored to their natural state as often as they fall therefrom, these changes would at once destroy and utterly break up their essence and harmony.* In respect to the perfection of more simple entities relatively to compound entities see Transaction I., n. 614, 615, 616. From this is follows that the most simple fibril, that, namely, which constructs that little canal which is properly called fibre, is the most perfect of all; after which comes the above mentioned channelled fibre; then the fascicle of fibres; and lastly the nerve, which, in itself, is rather to be deemed imperfect. But the most simple fibril which flows into the compound fibre, determines and rules that fibre, and restores it to its natural state as often as it falls away therefrom; and in like manner does the compound fibre act in respect to the fascicle, and this in respect to the nerve. But as to the manner in which the bloodvessels concur to the preservation and restorations of the nervous structure, the present is not the place to treat of this subject, for we have not yet treated of the origin of these vessels as being from the fibres.

245. *In the whole system, there is not a single fibre, still less any fascicle of fibres, and still less again any nerve, which in respect to all its accidents, is wholly similar to any other. Moreover, in the single subjects or individuals of the animal kingdom, they are so varied that there is not a fibre, fascicle or nerve in one which is absolutely similar or equal to that in another. Nay, if there were myriads of earths, and if in each earth, myriads of inhabitants were born every moment, yet, in this perverted state, there could never be a fibre of one exactly similar to that of another in respect to character, nexus, form, determination, anastomoses; that is to say, in respect to all essentials and accidents. This is confirmed by the marvelous variety which we find in individuals, in whom the single parts of each member are just as distinguishable from each other, as the individuals themselves are distinguishable by their outward appearance. For we are born, not only into the mingled form of both our parents, but also into their animus and habits. The animus of the mother is changed times without number in the space of a few days or hours; and a similar change flows into the fibrous and nervous system, wherefrom the form and the imaginative force of the pregnant woman is derived into the body of the embryo, which is marked in due conformity thereto.* Confer Transaction I., n. 267. *To these also are added changes arising from constant variations in our own animus.*

246. *The first cause of all changes and varieties in the nervous system, and in the external and internal forms arising therefrom, is derived from the diversity of ideas and principles existing in our minds, which determine the most simple fibril, and induce upon it a change of state. Another or secondary cause arises from the variation of animuses or affections, which so inscribe themselves on the countenance that they are plainly apparent. For their influx into the animal spirit and its fibre is so efficacious, that I would venture to say that in the animus, there is not a single motion repugnant to the natural motion of the body and mind, which does not carry to the fibres and least vessels, some force, and consequently some variation; such affections, for instance, as anger, envy, fear, sadness, etc. The third or last cause arises from a change in the blood, whence come sicknesses and diseases of the body. For the red blood is the treasure-house and seminary of all things in its body, and, after resolution into its elements, it runs through the whole structure of the nerve.* See above, n. 200 *seq. Therefore the whole nervous system is affected according to the state of the blood, and this to such an extent, that by reason of bad blood fibre is often dissociated from fibre and fascicle from fascicle, beds are loosened up, connections broken, passages hollowed out, and spurious plexuses and ganglia raised up; or, on the other hand, fibres, fascicles, and tunics are agglutinated, passages stopped up, distinctions obliterated, tumors formed, and structures eaten away, cut off and destroyed; as is abundantly learned from the several diseases, of which there is an host, and from an examination of dead bodies.*

247. *But vitiation of the blood does not extend to the simplest fibrils. These remain in their integrity, entirely immune and free from all essential change, whatsoever the assault made by diseases of the body. Nor does this fibre suffer aught except from the desires of ends in the mind, those, namely, which are repugnant to the order of nature.*

248. *Moreover, the fibres and their fascicles and nerves are changed by time. For in first infancy they are in the utmost integrity, soft, almost fluid, obedient to the laws of their nature, and unanimous. Principles do not then wage war with*

affections, nor affections with effects; for then is the time of the Golden Age, and the kingdom is ruled by Astræa. But as we decline through our periods even to old age, the fibres and their fascicles and nerves, grow obsolete, become hard, resistent, disobedient to nature, discordant. Principles then wage war with affections, and affections with effects. Then is the time of the Iron Age, and the kingdom is ruled by the Furies,† together with the rest of the Plutonian crew. Thus we grow weaker every moment, and are snatched away to death.*

CHAPTER XV.

THE SIMPLE FIBRE.

249. *The fibre of which we have hitherto treated is not the most simple of all; for it is a little passage or canal for that subtle fluid which is called the animal spirit; and it is girt about with the most delicate membranes or the softest meninges.* That this fibre is girt about with a certain most delicate meninx, or that it is a subtle membrane,—since it is a little canal, transmits spirit, and is distinguished from the neighboring fibres,—see above, n. 209. That this tunicle is the most simple of all the tunics of the body, and consists of fibrils pure above all imagination, see n. 210; and that this tunicle is double, n. 219. *For in order to the existence of a little canal which shall be distinct from other canals and shall transmit spirit, there must of course be a surface or tunicle. This tunicle ought certainly to consist of those fibrils which we call the most simple. The same thing moreover is taught and con-*

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*Astraea was the Goddess of Justice, and is represented as holding a pair of scales in one hand and a sword in the other. She lived upon the earth during the Golden Age, which is, therefore, often called the Age of Astraea; but in the Ages of Brass and Iron she was driven to heaven by the wickedness and impiety of mankind.

†The Furies, Latin, *Eumenides*, Greek, *Erinnyes*. Our author uses the Greek word. The three Furies were employed in inflicting the vengeance of the gods upon the wickedness of men. On earth, this was done by wars, pestilence, and dissensions, and in hell, by continual torments.

firmed by the cortical gland from which the fibre is produced. For according to the description, this gland, like a little heart, is furnished with a minute ventricle or follicle and also with a certain superficial materia which constitutes the body of the gland. Confer Transaction II, n. 124-126, 132, *seq. This follicle and also the superficial structure is continued into the fibre and through the fibre. For the fibre is the continuation of the cortical spherule, like as the artery is a continuation of the heart. Hence this glandular or cortical surface must necessarily consist of fibrils the most delicate of all, co-ordinated together in the most exact manner.*

250. *In the subjects of the animal kingdom this simplest fibril is deservedly to be called the first, supreme, inmost, most remote, most universal and most perfect fibre, yea, the one only continuous substance from which all other continuous substances, howsoever many they be, derive their existence, subsistence, nature and faculty of action.* I make a distinction between continuous and contiguous substances; or, what is the same thing, between coherent and fluid substances. For continuous and coherent substances constitute tunics, while contiguous or fluid substance permeate the little canal formed by the tunic. For example, the tunic of the artery is a continuous or coherent substance, while the blood is a contiguous, or fluid substance. It is called contiguous, because the parts are merely contiguous to each other, and after the contact are just as easily separated as if they had never been contiguous. Continuous parts are indeed also contiguous, but this at many points, and, therefore, they cohere. *So that to this fibre can be applied the philosophical canon: That in the animal system, in that it is animal, there is nothing that is truly substantial except this fibre, and that the rest of the compositions consist of mere accidents.*

251. *Moreover it is proper to predicate of this fibre that it is the pathway of the determinations of the soul, and, as it were, the ray of its intellectual light, and the veriest force of forces and form of forms in its kingdom. From which predicates it follows that animal nature herself and the state and condition thereof depends principally upon this fibre. For this* *fibre is the nourishing parent of both the cortical and the medullary substance, and in the body it carries every point.* These positions will come to be better explained in what follows.

252. *But the nature of this fibre cannot be learned except by the analytical way, that is to say, by abundant experience drawn from things posterior and from phenomena investigated physically and philosophically all the way to their causes and principles; for it is utterly remote from the perception of the senses, and goes beyond the sphere of anatomy. Hence our primary concern is that we may come to a knowledge of the essence and nature of this fibril, for on this knowledge depends the understanding of the causes, and the inmost understanding of the phenomena in the whole of this noble kingdom. For even though we know all other things, still they are merely effects, and the entire product of those infinite forces which flow forth from the potencies and principles of this fibril; and thus we really understand nothing if we are ignorant of this fibril in respect to its quality.*

253. *In general it must be held that it is necessary that this fibril also be transpirable, pervious, gifted with a most highly minute cavity, and thus be an image in least effigy of the larger or compound fibre; otherwise neither this fibril nor anything whatever in the animate body could derive and carry on its origin, progression, order, law, motor force, life and sensation; in that the fibril without a perfluent fluid or some analogue of a fluid would be a stamen impotent of action.* And this for the same reasons as those adduced above, n. 142, 143, in respect to the medullary fibre.

254. *That uttermost fluidity or fluid, so called by eminence, which flashes through this fibril, can be no other that that first and pure essece, truly animal and partaker of life, which is called the spirituous essence, and which is conceived in the inmost penetralia, vesicles, and fistulas,—also so called by eminence,—of the cortical glands, and is brought forth and transmitted in accordance with every need of nature.* Confer Transaction II, n. 165-167. *And since there is no other fibre that is more simple, it follows that this same essence forms that* *fibril's delicate tunicle or likeness of a tunicle.* This essence or uttermost animal fluidity has been treated of in Transaction II, chapter III, [On the Human Soul, n. 208, *seq.*], and frequently elsewhere. Moreover, I shall also continue the thread later on. Meanwhile I think no one can deny that in the animal kingdom there is a certain essence or substance proper thereto, —just as there are essences and substances proper to the vegetable and mineral kingdoms,—which is the first, inmost, and most universal essence, and from which are all the rest. Unless we concede this to be the case no physical law nor any philosophical dogma could have any place in the animal kingdom. On the other hand, if we do concede it, the several particulars come into agreement, and all the phenomena are explicable in agreement with those particulars. An essence of this kind, most facile for the undergoing of accidental mutations, (respecting which see above, n. 241),—for this is the perfection of superior entities,—cannot do ought else than, by a mode of constriction, put on a nature less fluid according to all degrees; and the reverse also is true. For how can this be impossible to the most perfect entities of nature, when the less perfect and the compound, that is to say, elastic bodies exhibit the same phenomenon? Thus nothing can be more easy to this essence than the building of a tunicle from itself, or, if I may so say, from its own materia.

CHAPTER XVI.

THE SPIRAL FLUX OF FIBRES; AND IN GENERAL HOW FORMS ARE EXALTED BY DEGREES INTO MORE PERFECT FORMS.

255. *The essence and nature of the simple fibre must be thoroughly explored if we are to have a profound understanding of the causes of the effects and phenomena occurring in the animal kingdom.* According to what was indicated just above, n. 252. *To this end inquiry must be made as to what is the form of the fluxion or motion of simple fibres, what that* *of medullary fibres or those which arise from simple fibres, and finally what is the form of the fluxion of bloodvessels; for the fact that bloodvessels are derived from fibres will come to be demonstrated in the sequel. From a knowledge of the form of the fibre comes a knowledge of its essence and nature; for essential determinations are that which is called form; and from its form comes the ability of the fibre to act in this manner or in that, that is to say, to be such as it is, yea, even to be.* Because, as was said above [n. 252], our concern is that we come to a knowledge of the essence and nature of this fibril; for neither essence nor nature is explored apart from form. "Form (according to Wolff) is that which we call essential determinations. He understands the form of the human body who understands not only its structure and hence the figures of its organic parts and the manner in which they are interjoined, but also the combination of similar parts whence organic parts are composed." (*Ontologia,* § 944.) And further on he says, "That an entity can act in a given manner is from its form; hence the scholastics affirm that form contributes operation to thing." (*Ibid.* § 946.) "Form therefore is the beginning of an entity upon which depends the existence of such an entity; consequently it is the cause of the entity." (§ 947.) And Aristotle says, "Every single thing is to be called a thing by virtue of the fact that it has a form." (*De Nat.,* Lib. III, Cap. i.)* Thus the truth is confirmed that the quality and mode of action of an entity depends on its form. Wherefore an entity without form would be devoid of all quality and mode of action, and thus could not be anything. I speak of the entities of nature, and not of those which are above nature, such as the spiritual and the divine; for with respect to these neither quality nor mode nor accident can be predicated except by supereminence.

256. *But we cannot come to a knowledge of the simple fibre except by the analytical way, that is to say, by progressing*

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*We are unable to find this *specific statement* in the passage referred to, though there is no doubt that it expresses the philosopher's teaching.

from visible phenomena through the connection of causes to invisible, or from bloodvessels to medullary fibres, and from these to the simple fibre; for the latter is far removed from the senses, and is the inmost or supreme fibre of its kingdom. Afterwards, when by the analytical way we have arrived thus far, we may be permitted to descend thence by the synthetic way.

257. [FIRST] *As regards the form of the fluxion of bloodvessels,—both those which are called arterial and those which are called venous,—this form is absolutely* CIRCULAR, *nor do they strive into any other form. For their muscular tunic which presses on the enclosed sanguineous stream and pushes it forwards is woven of annular fibres or muscular circles densely compacted together.* See Transaction I, n. 182-186. *Every constrictive force of this tunic strives from so many peripheries to so many centres, which latter constitute the middle axis. The blood globules themselves, which are rolled down within a tubule of this nature, are also circular in figure; and moreover are circularly rotated around their axis.* According to the ocular experience of Leeuwenhoek, who says, "When I examined blood in which was a quantity of chrystaline liquor, and carried the little tube [wherein it was contained] to a place where the wind was blowing, I observed that the globules were set in motion, like the air itself, by concussions and also mutually among themselves; and moreover I observed in the globules another kind of motion, namely, that each globule gyrated round its own axis." [*Philosophical Transactions*, n. 106, p. 129, 130; Trans. I, n. 29.] *Thus the tunic of the arterial vessel is wholly conformed to the nature and mode of the fluxion of its fluid, and* vice versa (see Trans. I, 134-5, 522); *and both conspire to the circular, that is, to the spherical form of motion. Hence is clear, what is the form of the fluxion or undulation of the sanguineous volume within the arteries; namely, that it is similar to that in waters,—a fluxion or undulation which widens out through continued circles from the beginning of the motion to its ultimate bounds.* See Transaction I, n. 166-176.

258. [SECOND] *As regards the form of the fluxion of the* *medullary or nerve fibres, this is not simply circular, but is a form superior to the circular and to be called the* PERPETUO-CIRCULAR, *or, properly speaking, the* SPIRAL. *For whenever a fibre is loosened from connection with the neighboring fibres and left to its own law of fluxion, it twists itself after the manner of a spiral, howsoever stretched out it is into a kind of line when held bound up in a bundle of many fibres,—the case being not unlike as with a twisted silk thread.* But since, as I have indicated above, we must pass to a knowledge of the simple fibre by the analytical way or the way of experience, it is necessary that I establish the spiral flux of this fibre, as I have previously established the circular flux of vessels, by ocular testimony; otherwise, it will seem perchance like a hypothetical assumption. There are indeed many of the learned who recognize this fluxion of the fibres; but Leeuwenhoek by his observations has proved it beyond a doubt. See his figure 7, [n. 34, above], which he describes as follows: "Although I had no doubt that the nerve fibrils, howsoever fine they might be, were so formed as to be accommodated to the making of contractions and expansions, nevertheless I wished to investigate this formation and see it with my own eyes. I therefore made longitudinal sections of various filaments of little nerves, and by aid of the microscope I had one of them delineated, as shown in fig. 7, where it is marked MNOP. In this figure the vessels which serve for carrying down the juices of the nerves, so far as they are extended lengthwise, are seen to be convoluted into *spirals* or *gyres.* It must be supposed, however, that in every extension of the nerve these parts stretch their gyres out into a straight line. By MN, OP is designated the tunic which, as I have shown, is surrounded by its several nerves." [n. 33.] Elsewhere, the same author says, "When I separated from each other those parts of the nerves which perform for them the use of vessels, I saw them *convoluted and curved into spirals after the manner of snakes.*" [n. 39.] "I carefully cut out two filaments hardly thicker than a double thread such as is used by tailors, and no longer than a finger-joint. When I examined their other extremity I found nothing there except certain little parts mutually *convoluted* and *contorted.* At various points lay two or three filaments mutually involved and complicated, with only a little interjacent matter. Nor was I able to bring to mind the probable cause of this convolution, although I had no doubt that the filaments used in this examination were truly nerves." [n. 31.] It will be of use also to here bring forward what the same author mentions as to his investigations with respect to the contorsion of tendinous fibres: "I placed under the microscope (he says) a minute portion of a tendon cut straight or longitudinally, and I clearly recognized that the tendon was compacted of six or eight smaller tendons. In each of these tendons *the form was a spiral one,*—a form which, in the motion of bodies, seems to be especially adapted for contraction and expansion. Furthermore, I have had delineated a minute tendon [which was adjacent to the outside of the tendon just mentioned]. It is shown in fig. 17 by the letters KL. Here *may be seen the spiral parts, or parts revolving or rotating in a gyre,* and which lie on the tendon just like *the thread or edge on a screw.* And indeed nothing can be imagined more suitable for the exercise of expansions and contractions than this spiral figure and rotable nature. Nor is that spiral figure and that form of circumvolutionary parts confined only to tendons, for neither is it wanting in the fleshy fibrils which are annexed to the tendons." [n. 42.] "After the parts of the tendon had been separated, we then recognized in them those small and *snake-like spirals.*" [*Ibid.*] "In the legs of the flea I can most distinctly recognize not only tendons and fibrils, but *also the spiral* and *volutionary contraction of the fibrils,* which, as I can clearly discern, is also not wanting in the muscles of the flea." [*Ibid.*] "In the flesh of the wild bee also I have observed spiral extensions and contractions." [*Ibid.*] I have desired to here adduce the observations of this renowned author respecting the spiral fluxion of fibrils over tendinous fibres and motor fibres of muscles, in order also that thereby may be confirmed the following induction, namely, that the fibre when released from the bond of neighboring fibres, strives into no form more freely than into the spiral,—as for instance when fibres unfold themselves in muscles and elsewhere. *At its end* *where it enters upon the work of constructing its organic forms this fibre loves to flow around into no other form more freely than into that of an helix. Likewise in its cortical gland whence it issues, and which, being most perfectly convoluted after the manner of a screw, carries on its expansions and constrictions in no other way; hence a similar effect redounds to the fibre which is produced therefrom. Thus, as is the weaving of the principle such is the web brought forth therefrom.* This fibre flows from the cortical gland like a thread released from a twisted coil. But as regards the gland itself, the keenness of the sight, even when armed with the microscope, cannot indeed penetrate so far as to be able to distinguish the simplest threads of its texture; and yet I deem that it cannot be denied but that these threads are disposed in most perfect order and in accordance with every mechanical potency of nature. On these matters consult also Transaction I, n. 301, 302, 303. Thus then, not only from the experience of things visible but also from the connection of causes, this phenomenon is rendered indubitable,—to wit, that the cortical gland, in respiring, expelling fluid, and producing fibre, makes spiral gyres. *The fluid itself which courses through this fibre all the way from the cortical gland to the end, seems to wind itself, both as to parts and as to volume, into the form of a similar gyre. For a tunicle is exactly conformed to the nature of its fluid, and a fluid to the mode of reaction of its tunicle; since in this way and in no other do tunicle and fluid act together as one cause.*

259. [THIRD.] *As now regards the form of fluxion of the simple fibre which produces the tunicle of the aforementioned compound fibre, this form cannot be simply spiral but must be superior to the spiral. For as forces and substances are elevated by degrees, so they are elevated into a superior and more perfect nature and potency. So likewise with this form of fluxion, which therefore merits to be styled the perpetuo-spiral, which in the following pages we will call the* VORTICAL. Just as the circular form when it is elevated into a superior form is called the perpetuo-circular, or more properly, the spiral, so this form is called the perpetuo-spiral or vortical;

for what is superior must also be designated by another name,—according to the fourth rule laid down in Transaction I, n. 648. *And since this fibre is likewise transpirable and pervious and carries a certain purest essence proper to the animal, and which at the same time constructs the highly delicate membrane of the fibre itself, therefore from the connection of these same causes it follows, that such essence,—if it be compared with a fluid,—when it courses through the fibril, winds itself, both singly and in general, into gyres of a similar spiral; and this by virtue of the same law, namely, that fluid and tunicle are most exactly conformed to each other, and unless the one together with the other be understood, there is no fibre.* Consult n. 253, 254.

260. *But because the essentials and formals of this fibre lie deeply hidden within visible nature, therefore it is not to be wondered at, if the mind also, which is a superior sight and is enlightened by the light of its external senses, here begins to grow dull, and, as it were, blind, or to enter into a kind of shade, that is to say, to be ignorant as to what the perpetuo-spiral or vortical form is or what its nature, and hence to doubt its existence. To this end therefore, I wish to ascend from the most imperfect form to the most perfect, to the end, namely, that an idea of the one, that is, of the more perfect, may be acquired from a perception of the other or more imperfect by the aid of elevation from power to power; just as in the case of the infinite calculus; for thus we acknowledge, even though we do not comprehend.*

[THE DOCTRINE OF FORMS.]

261. *The most imperfect form, which is also the ultimate of forms, is the* ANGULAR; *and it consists of angles and interjacent planes, and is bounded by mere straight lines which are determined not to any common centre but to other directions. This is apparent in triangles, quadrangles, etc.; for if lines be drawn perpendicularly from any point of the planes they do not flow together or meet in any given centre, but perpetually intersect each other.* In the circle, however, all lines drawn from the surface are concentrated in a single point; and if, by any external force or by pressure of the fingers, you wish to reduce a circle or sphere, wherein interiorly there is a determination and nature of this kind, into a triangular form so that it shall remain triangular, the determinations themselves must necessarily undergo change; that is to say, the lines which converge in the centre or aim at the centre must remove themselves from the centre and look for their terminations to other points outside the centre,—in which points, moreover, they are met by other lines let down perpendicularly from another plane of the triangle; otherwise the form springs back into its own sphere. That straight lines thus determined do not produce any perfect form was also, I see, held by the Philosopher of old where he says: "A circle is perfect, but no straight line is ever perfect; for neither is it boundless, since it must have a term or bound, nor is any manner of things bounded perfect." (*De Coelo,* lib. I, cap. ii.) And further: "Local motion in a straight line is not suited to nature;" for "motions which are effected in a straight line are opposed to each other by reason of their positions . . . since each single position is always distant from the other by a straight line." (*Ibid,* cap. iii, iv.) *From the above it is apparent that in these forms the determinations are opposed or more or less contrary to each other, that is to say, meet each other more or less obliquely or directly; wherefore, at every point of section and meeting, the progression is stopped, the fluxion terminated, and the forces extinguished. Hence it comes to pass that such forms, in themselves and their own nature, are altogether unsuited to the continuation of motion, and are the verimost forms of rest and inertia. And by such meeting of lines there arises profound rest not only in the internal structure itself, but also among several forms when mutually applied to each other. For on their external surface they are in like manner angular, that is to say, are furnished with planes and angles,—for as is the essential determination such is the termination, or, what comes to the same thing, as is the form such is the figure which is the limit of the extense,—and angles are so many points of hindrance and planes so many points of coherence. Not one of these forms can be* *rotated around any axis, still less around any centre (which, indeed, they lack), since angles and corners impede; and if planes come together they are joined into one.* Thus every angular form is to be conceived of as being intrinsically a coalescence of mere trigons or little cubes,—just like the mass in the larger effigy into which they coalesce when a number of them are mutually applied to each other in one space; for they cannot be rotated unless all the neighboring forms yield place. *Therefore these forms are the most imperfect and are endowed with the force of inertia. Thus they are proper to the earth, and are the same as those which are called saline, acid, alcaline, urinous, sulphureous, nitrous, mineral and vitriolic.*

[261a] *The triangle in planes, or the trigon or tetrahedron in solids, is the first and as it were the simple of angular forms; for to these, all the rest, howsoever compounded they are, refer themselves, and to these are they reduced if they are to be resolved. Of triangular forms the most perfect is the equilateral or equiangular, while the scalene are more or less imperfect. The quadrangle in planes and the octohedron in solids is the second of the angular forms, being compounded immediately from the first. Of quadrangular forms the most perfect is the equilateral and equiangular; the rest are more or less imperfect, such as parallelograms, rhomboids, trapeziums, or forms wherein the sides and angles are more or less unequal. After these come polygons and multilaterals, which in like manner are regular and irregular and consequently more or less perfect or imperfect; the last of these forms exceed all number. Thus angular forms are distributed into genera and species.* "Since specific difference (according to the teaching of Wolff) consists of essential determinations, and by the same determinations is determined the genus and species of an entity, therefore it is by reason of its form that an entity belongs to a given genus or species and is distinguished from other entities." (*Ontologia,* § 945.) *From these considerations it follows that the first of the angular forms are most minute tetrahedrons and octohedrons; which therefore are to be called elements, primitive entities, and the principles of salts and sulphurs.* Compare Transaction I, n.

69-79. *These, together with their compounds, are so many hard and inert corpuscles incapable of motion among themselves except by the aid of fluids; truly heavy, material, extended, figured; of themselves fixed and fixing; not expansible or elastic; frigid; tempering in divers modes the fluidity and heat of active forms; but most highly suited for the formation of various compounds. For without them neither earth would exist nor the vegetable kingdom nor the animal, nor, in a word, the visible world. These forms are what affect the sensories of taste and smell with so great variety; and they properly constitute that part in every animal which we call the body. These, moreover, are the forms of which geometry, trigonometry, physics and chemistry treat scientifically.*

262. *But lest we halt uncertain in the significations of words, it must be explained at this threshold what* FORM *is, and what* FIGURE. *Form is the essential determination or the determinate fluxion of parts, points, substances, forces. Thus we have the form of motion, the form of modifications, and the form of substances,—all of which forms coincide. Nevertheless no idea of forms can be conceived of apart from the idea of fluxion. Figure, however, is the limit of an extense or the termination of such fluxions, that is, the terminus of essential determinations. It is sometimes called external form.* Meanwhile this definition of form is in agreement with ancient and modern philosophy. There are indeed essential determinations or forms of which neither terminus nor limit can be predicated, consequently neither figure,—such for instance as spiritual forms; but yet these predicates must be understood of such forms by analogy with things similar; or, they must be predicated by eminence; for termini and limits are not possible unless there are parts, and these must occupy space and must form an extense. But to resume. *External form is born after the image of internal form, but not the reverse. For if from an angular form the angles are cut off and the planes rounded, the form is turned into one that is spherical or more perfect; but the internal form still remains, that is, the former essential determination and the whole of the quality thence resulting and ingenerated. Furthermore, from* *the figure, when not changed, is known the quality of the form; as, from the countenance the quality of the animus.*

263. *The next superior form is the* CIRCULAR *or* SPHERICAL *form wherein are no angles and no planes. For in order that angular forms may be elevated into this next superior or spherical form the angles must be cut off and the planes so rounded that no part of them remains; and therefore this form deserves to be called the* INFINITELY ANGULAR *or the* PERPETUO-PLANE. For it is an image of something perpetual or infinite relatively to that which in angular forms is finite. What is perpetual is also a unit; thus when there are no longer a number of angles nor a number of planes, there is in this form as it were one common angle or one common plane. This also comes about naturally when angular forms, in a volume composed of many such forms, are forced to turn about their axis; likewise when they are held by an engirding flame that licks them about; for the angles being then cut off, the forms are rounded, and with the help of nature are adapted to an axillary motion among their neighbors; moreover, the longer the motion persists, and the more swifty, that is, the more forcibly, they are driven around, the more are they liberated from the form of rest, as they put on extrinsically the form of a most perfect sphere. *But nevertheless there remains what is linear; for the semidiameters or radii are so many straight lines let down perpendicularly from the periphery.* The two lines are let down; for in the circle we must consider that as being upwards which is towards the centre, and that as being downwards which is towards the periphery; as is also the case in the great spheres, such as our own, where the centre of the earth is in the lowest place. *Hence it follows that the spherical form is the verimost form of motion, and that it is most highly potent for resistence, most constant in remaining in its own essence, and, in company with angular forms, most highly accommodated to every ratio of composition.* But let us take these several points in order.

[i] THAT THE SPHERICAL FORM IS THE VERIMOST FORM OF MOTION *follows from the fact that it is void of angles and planes, since angles are so many points of hindrance and planes*

so many points of coherence. For many spherical forms or globules rotate around their axis most freely in one volume and in one circumscribed place, nor does one move another from its place, nor touch it except in the least and a similar point; and after the contact it almost instantly recedes and rolls away with the plane itself. Wherefore angular forms when put in motion and driven around among themselves, are turned as in a lathe by the mere force of the motion; that is to say, their angles being cut off, they are rounded, and with the help of nature are adapted to an axillary motion among their neighbors. Thus they are in the utmost readiness to gyrate around some axis,—for there are as many axes as there are diameters, —but not around a centre unless the linear directions are changed into circular and a spiral determination results. For in more perfect forms there is an axillary motion and a central motion, on which two motions depends the nature of fluidity, undulation and modification. Moreover, the smoother they are superficially, the more fitted are they for the continuing of motions; while the rougher they are, the more unfitted. Thus, of such forms of motion, there exist those that are more perfect and those that are more imperfect. The very determination of the interior lines in the circle or sphere also conspires to making this form the genuine form of motion. For semi-diameters, like perpendiculars drawn from every point of the periphery, flow together into one and a common centre; nor do they meet each other at any other point on the way,—as is the case in angular forms, where the points of meeting are so many oppositions, and the oppositions so many causes of inertia, which are perpetual and infinite. From the confluence of the determinations to one single centre it follows that axillary gyration agrees with the form of nature herself; for there is nothing outside the centre that hinders the revolution, and each single diameter must represent an axis. That a diameter represents an axis follows not only from the fact that one diameter is distant from another, and that one is ever presenting itself as an axis, but from the further fact that the spherical form must be considered as consisting of mere concentric circles all the way from the ultimate periphery to the centre. For circles are formed if from any one point of a diameter perpendicular lines are projected, since these lines when simultaneously continued describe a line perfectly circular.

[ii] THAT THE SPHERICAL FORM IS MOST HIGHLY POTENT FOR RESISTANCE, *or is resistance itself against all manner of external attacks and assaults, is evident from the fact that all the lines, like so many radii, meet in one common centre wherein is such absolute opposition, both as regards the several lines and as regards the whole of them, that one cannot be moved out of its place unless another is moved at the same time. Thus the forces are conjoined and the one protects the other lest they fall apart. This is the cause of the resistance in the spherical form,—a resistance which decreases in proportion as there are more centres to which the determinations are diffused.* As is the case in the elliptical or oval form wherein are two centres, and in the other curves wherein are many centres. For it is the regarding of the centres by the periphery,—from which the perpendiculars flow,—that measures the degree of resistance. In the circle, all the lines, or, if instead of lines we substitute forces, all the forces, have regard to one single centre wherein they all meet together in every possible relation of opposition. For in this centre one line regards one other as diametrically opposed to itself, and the rest as obliquely opposed, and thus as opposed in every perceptible obliquity. *Wherefore it may be said that there is nothing more inert, hard, resistant, and frigid than what is found in the centre of this form.*

[iii] *From these considerations it also follows that* SPHERICAL FORMS ARE MOST CONSTANT IN REMAINING IN THEIR OWN ESSENCE *howsoever the modes may be varied. For the determination of one line is most highly similar to the determination of another, nor can it be changed unless at the same time all are changed,—and to prevent this, one protects all and all one. For from the centre each single line regards and as it were contemplates the universal state of its form, and in the centre it feels all that happens to a neighboring line.*

Granted then that the essential determinations in the circle or sphere are not the massed lines or radii, or hard cor-

puscles, but that they are innumerable smaller spherules and in these still smaller which are more perfect forms according as they reside more interiorly, it follows that an entire sphere of this kind, composed of smaller spheres enclosed in due order, is highly elastic and yields superficially to every inrushing or attacking force. For if the smaller spherules are most highly yielding, the larger sphere which is their total or complex cannot but likewise yield, that is, be endowed with the power of elasticity. Conceding then that spherical forms are most highly constant in their essential determination, it follows that from no accidental cause can such forms, howsoever they may be pressed upon extrinsically, be reduced from their spherical form or be transmuted into another, still less into an angular form; but that, whenever urged, they are compressed into spheres of a smaller diameter or dimension, and with the removal of the urging force they straightway relapse into their pristine expansion. Thus the variation of their modes consists in their suffering themselves to be constricted into a smaller spherical space but not into any oval form. Thus also they answer to every ratio of the invading forces, and, with a minimum loss of forces, react in the degree that they are acted upon. For the more the spherules become constricted the more firmly and hardly do they resist, and this until they have increased their resistance to the ratio of the forces acting from without. This follows from the rule that nowhere is there anything more inert, hard, and resistant than in the centre of such forms, and thus in other places in proportion to their distance from the centre. That the parts of the atmospheres are such forms becomes manifest from the several phenomena observed in the air.

[iv] THAT SPHERICAL FORMS IN CONSOCIATION WITH ANGULAR FORMS ARE MOST HIGHLY ACCOMMODATED TO EVERY RATIO OF COMPOSITION *is apparent from the fact that primordial particles, saline, sulphureous and mineral, are not simply angular forms but are mediate between the angular and the circular. For they are so many minute trigons and octohedrons exactly hollowed out to the convexity of spherical particles, such as water particles; thus they can be mutually ap-*

plied to each other and be suitably united into a larger corpuscle. It would be otherwise if their sides were plane and not hollowed. That primitive entities or saline and sulphureous elements are hollowed out at the sides suitably to the convexity of water particles, has been shown throughout in my works,—see also the whole of the first chapter in Transaction I, on the subject of the blood; nay, and also that their genesis must be derived from water, that is to say, that they are born in the interstices of water, and consequently are formed according to every convexity of the water particles. Hence arise not only octohedrons but also trigons. This has persuaded me that no saline element is entirely plane on any of its surfaces, for in such cases they could never be associated with any spherical particles whatsoever,—neither aqueous, nor aerial, nor mercurial,—since the two would touch each other only at one point, and thus would not be applied, united, and made coherent. From this principle it undoubtedly follows that there was a universal ocean prior to the existence of the earth; and that the crust of the earth was made up of elements originating between the water particles in the way described. *Hence come oils, spirits; the red blood, white blood. and the other humors of the animal kingdom* (compare Transaction I, n. 115); *essential juices, tinctures; nay, even the more solid particles such as the sulphureous, saline, stony, crystalline, mineral; and all vegetations,—the elements whereof, which are in the angular form, could never coalesce without the presence of interjected globules and without mutual embraces or kisses.*

[263a] *Moreover the circular or spherical form is the measure and form of all angular forms, and thus as it were their universal type and complex. For without the aid of the circle, angular forms and figures can never be measured, still less be reduced to calculation. This follows from the fact that the spherical form is perpetuo-angular and infinitely plane; and what is perpetual and infinite must give the law to things changeable and finite, and judge them as to their quantity and quality. The superior form moreover is always prior; hence the angular form is produced by the circular, on which account the latter is the measure and form of the former.*

[263b] *Of the circular or spherical form also, there are genera and species. The genera are either more or less perfect or more or less imperfect, and so likewise the species.* For we have elliptical or oval forms; we have cycloids, parabolas, hyperbolas, and many other forms both geometrical and arithmetical;* all of which have been distributed by the illustrious Newton into their genera and classes. *The essential determinations of these forms are not indeed directed to one fixed centre but to several. Still the directions do not cross each other or approach from opposite quarters, as is the case in angular forms, but come together in a certain line or plane. These forms, therefore, are more imperfect and inert than purely circular forms, but more perfect and active than angular forms.*

264. *The form next superior to the circular, prior and more perfect, is the* PERPETUO-CIRCULAR *which is properly to be called the* SPIRAL. *For its determinations are not into continuous concentric circles, nor are they directed by means of radii or straight lines to any common centre; but they strive by means of continual spirals to flow towards a certain middle circle occupying the place of a centre, and towards its periphery or surface; through which circular surface they continue their fluxions, or strive to continue them, and from which, by means of radii, they look to the centre of their spheres,—just as in the perfect circle.* Thus in this form there is again something perpetual and infinite relatively to the circular form, as in the case of the circular form relatively to the angular. For the spiral is as it were a perpetual circular fluxion,—a fluxion, namely, from each point of the surface, which is the limit of its fluxion, through a perpetual spiral winding, towards a spherule occupying the place of centre. Thus each spiral represents at the same time both the circle and the semidiameter, that is to say, the determinations of each. Thus the semidiameter is everywhere, and the circle everywhere, that is, it is perpetuo-circular. This fluxion is terminated, as was said, in a certain spherical surface in the centre; but the determinations never meet each other, but flow unanimously and with due obliquity into all points of that surface, and so continue the gyre. For when all the spirals terminate in a circular surface of this kind, it follows, that if the central spherule consists of angular forms, it is movable around its axis; or if it consists of spherical forms, the latter flow around in a circular manner. This central spherule is not unlike our terraqueous globe floating in its atmosphere, which revolves about its axis, and into the surface of which are determined as it were the continual spirals of the etherial atmosphere. If we wish to explore more deeply into the nature of prior or superior substances it becomes quite manifest that those substances which by their fluxion describe this form are endowed with such a nature that they can flow in no other way,—as has been abundantly shown in my Philosophical PRINCIPIA, where also I have taken pains to delineate the very form of the fluxion. *Thus the spiral form enters into the circular, and by means of the circular form, it regards the angular not as actually existing within itself, but as potentially able to exist.* According to the proposition adduced above, to wit, that the angular form is produced from the circular, and that therefore the latter is the measure and form of the former. But the angular form is not produced immediately from the spiral, for this would be contrary to the nature of derivation, since singulars can be unfolded only successively. *For whatever is the cause of the cause is also the cause of the thing caused; and therefore the spiral form is the measure of the circular form, and thus the form of all the forms that follow.* "The forms of the supreme world (says Aristotle) were called by the ancients Exemplars, wherein, according to Plato, is seated the substance of things inferior." (*Divina Sapientia secundum Aegyptios,* lib. XIV, cap. xiv.)

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*In the Latin this passage is printed in italics.

[264a] *This spiral form is a superior form of motion more excellent or still more perfect than the circular; or, it is the form of active forces. For here there is no concentration of determinations, but in the place where the spirals terminate there they are continued by circles. Here therefore we*

find some natural spontaneity. For in this form, a fluxion once commenced is continued with so easy a potency as to be almost spontaneous; and that nature has inscribed this faculty, potency, and force into the spiral flux is clearly apparent from the helix and screw in mechanics. That this form is a still more excellent form of motion is averred by Aristotle when he says: "Besides those bodies which are here and around us, there is another and distinct body, which has a nature as much more excellent, as the body itself is far removed from those bodies." (*De Coelo,* lib. I, cap. ii.) *For the circular form is voluble and rotable only around its axes or diameters, while the spiral form is voluble and rotable around a centre; which central fluxion or gyration is the same as a perpetuo-axillary or truly spiral gyration.* That circular forms cannot gyrate around a centre, or, that in such forms there can be no central gyration but only an axillary, has been pointed out above. Therefore for the existence of a central gyration there is required a more perfect form, or a spiral. Meanwhile, the manner in which central gyrations are effected cannot be easily expressed in words nor represented by a figure,—though I have attempted to represent it in my Philosophical PRINCIPIA; for when we ascend above the circular form the ideas of our understanding enter as it were a kind of shade. But to resume. If the fluxions are continued around the middle or around some central globe, it follows that a spiral gyration is possible. It would be otherwise if they were terminated in some centre.

[264b] *Hence also it follows that this form is still more constant than the circular in remaining in its own essence.* The constancy in the circular form has been treated of above. For the more perfect are the forms, the more constant they are, since they approach more nearly to the perfection of primitive nature. Wherefore they undergo essential changes with difficulty, but accidental changes with the greatest ease; for the faculty of undergoing accidental changes is the perfection of their nature. See above, n. 241. That nevertheless these forms can also undergo essential changes is evident from the fact that there are also genera and species of such forms.

But when they have undergone such change, they can be restored to their own nature and pristine perfection only with difficulty. For the greater the difficulty of their undergoing change, the greater the difficulty of their being restored; so that in the case of still higher forms they cannot possibly be restored, that is, cannot possibly return,—on which matter we shall treat more fully below. To resume.

[264c] *This form also has its genera and species; and the genera are more or less perfect or imperfect, and likewise the species. But terms and expressions are lacking whereby to distinguish them from each other according to their differences; for this form goes above the common understanding, because above ordinary geometry and its lines and circles, being placed indeed at the summit of this science.* That there are many genera and species of spiral figures is no secret to geometers. This, however, is not the place to designate the several varieties by name according to generic and specific differences, that is to say, to enumerate the differences. For spirals may be designated as circular, elliptical, parabolic, hyperbolic, geometric, arithmetical, etc., since, according to the nature of the spiral, there is formed on the inside a central globule or nucleus consisting of one of the above mentioned forms, and to this the external form corresponds. *Meanwhile, this form is obvious and conspicuous everywhere in nature and its kingdoms, since to it are due all the properties possessed by the circular form. Into this form flow the parts and volumes of the ether, and by its means they represent their modifications; so likewise in the animate body, the parts and volumes of the purer blood, and also the medullary and nervous fibres.* See above, n. 258. *In the vegetable and animal kingdom also they are frequently conspicuous.*

265. *The form next superior to the spiral form, prior and more perfect, is the* PERPETUO-SPIRAL *which is properly to be called the* VORTICAL. The reason for this denomination is that such forms belong properly to the superior ether which constitutes the great vortex around our earth, and within which also the moon performs its orbits and periods. I am not unaware of what modern authors think respecting the existence of this vortex, but this causes me no delay since the actual phenomena fully persuade me that they can be explained in no other way. *For its determinations do not aim, by means of spirals, such as we find in spiral forms, towards the surface of some circle or sphere, but, by a mode of perpetual spiral which we call a vortical spiral, they strive to wind themselves towards some globule or gyre of a spiral form holding the place of centre,—and indeed towards its surface.* The nature of the spiral, or of the vortical fluxion of spirals, can hardly be comprehended except by the pattern of a line composed of the circular line and of the spiral. For as the spiral line or fluxion is mediate between the circular fluxion and the rectilinear, so the vortical line and fluxion is mediate between the spiral fluxion and the circular. Whether the matter can be expressed in any other way I know not. *By which spiral surface they continue their fluxions, or endeavor to continue them.* For whether they continue them or endeavor to continue them it amounts to the same thing, since in endeavor are contained all the essentials of motion, and endeavor is the first and the last in every motion, and therefore is the actual existence and continuation of motion. *And from which, by means of spiral radii, they have respect to the periphery of some circle or to the surface of a sphere,—precisely as in the perfect spiral form,—and from this circle to the verimost centre of the sphere.* There is a similar ratio between this form and the spiral as between the spiral form and the circular; and therefore I use the same terms, except that they are applied to the vortical form by transmutation. Compare the preceding paragraph.* *Thus the vortical form determines and enters into the spiral, and, by the mediation of the spiral, the circular, and again by the mediation of the circular the angular,—which latter is within the vortical form not actually but potentially.* Thus is apparent how far removed is the angular form from the vortical; so that the latter regards the former from a long distance as it were, and as existing within itself not actually but only potentially; nor does it ever pass over into this ultimate form except by successive derivation. ***From which considerations it is apparent how great is the immunity of superior, prior, and more perfect forms from the injury of inferior, posterior, or, in themselves and their own nature, more imperfect forms.*** In relation to this form even the circular form begins to be considered as imperfect; for in itself and its centre it contains the principle of rest or inertia and also of gravity; but not so the vortical form, and still less the yet higher forms of which we shall speak below. ***Hence the vortical form is the measure of the spiral form, and thus the form of all the forms that follow.*** In each form there is a certain representation or exemplar, as the ancients called it, or, according to modern authors, a certain mirror or idea of all the forms that follow. For not the least thing can be derived from the prior into the posterior unless there be some image of that thing within the prior. To give to another something which oneself does not possess, or to produce something from nothing is contrary to nature; but that which is given is contained within the parent the more remotely according to its distance when, by successive derivation, it is unfolded.

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*In the Latin n. 264 is one paragraph which for convenience we have subdivided. The reference is to the first part of the number.

[265a] ***This vortical form compared to the spiral is a still superior and more perfect form of motion and is rather to be called the superior form of active forces, or of that conatus which lies within active forces. For within this form there is no least trace of opposition, but a certain natural spontaneity.*** The reason is because its radii or determinations tend to the surface of a highly active form, that is, of the spiral, and from this to the circle; thus its force of action increases in a threefold ratio. ***For the spiral form is able to gyrate around its centre, but the vortical can gyrate around as many centres as there are points in the periphery of the circle to which it has respect. Therefore the gyration of this form is to be styled a perpetuo-central, or, more simply, a vortical gyration. Hence also it follows that this form, compared to the spiral, is still more constant in remaining in its own essence.*** In respect to this matter see the remarks on the spiral form in the preceding paragraph [n. 264a, 264b]; the application follows of itself, for

it is a series of consequences. *Nevertheless these forms, like the inferior, are capable of undergoing a certain essential change,—but only with difficulty; and the greater the difficulty of their undergoing change, the greater, after the change, is the difficulty of their being restored to their pristine perfection.* This is a consequence. For, supposing a substance of this kind most constantly permanent in its form, the causes of change must by all means be such that the whole state can be essentially changed or perverted; such, namely, that not only is the spiral form, to which the vortical aims as to its centre, reduced to the genus or species of another form, but likewise the circular form, to which the spiral form looks as to its centre,—according to the proposition. Thus the very centre must necessarily be removed from its position and placed elsewhere. Therefore until this entire disposition is changed, that is, one form after another, no essential change is possible; and if it does take place, such change is necessarily in like manner permanent as was the constancy in remaining in its own form. But to resume.

[265b] *Of this form also there are genera and species, and the genera are more or less perfect or imperfect, and likewise the species. But here terms and expressions are altogether lacking whereby to distinguish them from each other according to their differences; for the idea of this form almost transcends the human understanding because it transcends geometry and its lines and curves.* Compare what has been adduced in the point above [n. 264c], and make a simple application. And because the idea of this form almost transcends the comprehension, it follows that in unfolding and perceiving it we are, as it were, in the shade of a kind of ignorance. Wherefore, because we do not penetrate to this form, neither do we admit its existence in the nature of things; in other words, we class the things predicated of it as among paradoxes and conjectures. But no matter. There are innumerable phenomena which confirm the actuality of this form and its fluxion. In nature there is an infinity of things which can never be reduced in an intelligible manner to any geometrical or analytical calculus, and yet we are persuaded of their existence. Thus there are many things the existence of which must be confessed even though

we be ignorant o their nature. Nevertheless the quantity of this form can be comprehended only like other forms which come under the infinite calculus raised to higher powers and which we are unable to resolve either by lines or by spheres. To resume. *This form is obvious everywhere in nature and is seen from phenomena; for to this form is owing all that is possessed by the spiral form, consequently all that is possessed by the circular, and finally by the angular. For into this form flow the parts and volumes of the superior ether, which constitute the great vortex around our earth; likewise, in the animate body, the parts and volumes of the purest blood or of that highly fluid animal essence which runs through the simplest fibres; and moreover, the simple fibrils themselves.* See n. 259. *To these forms is due the marvellous iron-attracting faculty of the magnetic forces, besides many other phenomena occurring around the magnet. For it is an evident truth that such a form can in no way exist by the fluxion of substances of this nature, unless poles be assigned to it, and greater and lesser circles, just as in the great sphere; so that in any vortical form, least or greatest, there necessarily exists a certain pole, arctic and antarctic, with the idea of an axis, and, moreover, an equator, ecliptic, meridian, the colures,* etc., which have been found by observation not only in astronomical bodies but also in magnetic. It is thus apparent that forms of this kind really exist in the universe of nature, or in the world.* That the magnetic force and its *attractio ferri* (attraction for iron), as it is called, and also its declination and inclination, has its origin in some ether whose parts and volumes, larger and smaller, flow according to the description of this form, has been shown at sufficient length in my PRINCIPIA; nor do I pause in doubt, but am fully convinced that the cause can be derived from no other source. But now to a form still higher.

266. *A form superior to the vortical, prior and more perfect, is the* PERPETUO-VORTICAL *form which is properly to be called the* CELESTIAL. The reason for this denomination lies in the fact, that this form is the supreme of all natural forms, and constitutes that great expanse which is called the celestial* expanse, and in Sacred Scripture, Heaven (Gen. I). It is also named heaven by ancient philosophers such as Socrates, Plato, Aristotle; and in common discourse we ourselves speak of the starry universe as heaven; but there are those who make a distinction between heavens. *Its determinations direct their windings by celestial spirals, like so many radii, to a certain vortical gyre holding the place of centre, and around it they continue their fluxions. From this [gyre] they have respect to the spiral form, and from this again to the circular, and from this to the angular. Thus the celestial form enters into and determines the vortical; by the mediation of this, the spiral; and by the mediation of this again, the circular, and so on. This celestial form is the natural principle of active forces, endeavors, and motions, and from it flow all other forces. For this form is the first and supreme of all the forms of nature, so that it might aumost be called nature in her first infancy.* Respecting first nature and that order wherein one thing depends upon another, Aristotle has some fine observations, where he says: "Every natural form has in the supreme world some other and similar form corresponding to itself but more noble. . . . An inferior condition (or state, *ratio*) depends on another, and conditions of this kind are many and singular. But that which is single depends on that which is universal"† (*Div. Sap. sec. Aegypt.*, lib. XIV, cap. ix); and

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*The colures are the two principal meridians, being two great circles intersecting each other at right angles in the poles.

**Coelestis* (from *coelum*, heaven), which here and elsewhere is translated *celestial*, might with equal correctness be rendered *heavenly*.

†The following is the complete passage from which the quotation in the text is taken: "We finally conclude that every natural form has in the supreme world some other and similar form corresponding to itself, but more noble. For in this world form depends on matter, but in the other it has not the least such dependance; and the former is an image of the latter. Wherefore in that world also there are fire, air, water and earth, as there are also plants. But if anyone shall say in dispute that such things are not possible in the supreme world,—for the reason that if they are there then they are necessarily either vital or void of life; but if void of life how can forms here have need of them? or, if

elsewhere, in the chapter on the different definitions of nature, namely: "Nature is defined in one way as the genesis of things nascent. Secondly, as that from which is born all that is born, the same being first existent within it. Again, as that from which arises, in each of the things that are in nature, that first motion which lies within it by virtue of the fact that it is itself. We say that as yet a thing has no nature if it has no appearance and form. Nature therefore is that which consists of both these. Strictly speaking, nature is the substance of those things which have in themselves for their individual existence, the principle of motion. But matter is called nature by reason of the fact that it is susceptible of this motion." (*Metaphysica,* lib. V, cap. iv.) ***This form is most highly constant in remaining in its own integral state, and if it is removed therefrom it can never be restored to all its pristine perfection.*** According to the points mentioned above, namely: That superior substances are capable of undergoing essential change only with difficulty, and the greater the difficulty of their undergoing change, the greater the difficulty, after the change, of their being restored to their pristine perfection (n. 265[a]). To resume.

[266a] ***The qualities which are predicable of the celestial form can hardly be expressed by terms or expressions applied to inferior forms, except by way of analogy or by eminence; for they transcend the common ideas of our mind, and even rational analysis and phil-***

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they are said to be vital, how did such things come into existence?—we shall answer that plants there are vital because they live here. But in the plant which exists above that mind which is proximate to matter and is conjoined therewith, (sometimes the plant is here materialized), there is a certain nobler condition (or state, *ratio*) effective of life. The truth is that there is a different condition (*ratio*) in the plant that is superior and primary to the plant here, and more noble; for this inferior condition depends on another; and conditions of this kind are many and singular. But that which is single depends on that which is universal. So from these considerations it seems to be brought about that our compound plant is a kind of branch of that universal plant. Wherefore if the plant here is vital, much more does it behoove that superior plant to be vital, which is the primary and true plant."

osophy. The quality of this form transcends the qualities of other forms. We understand the properties (*rationes*) of angular forms, and also of circular forms, in that they belong to geometry; but we little understand the properties of spiral forms, and scarcely at all,—indeed not even scarcely—those of vortical forms. When we have understood these, then certainly the principles of astronomy and the causes of magnetic forces will by no means be concealed from us. If our reason, supported by mathematical and philosophical principles, stops here, what hope is left us of penetrating to the qualities and faculties of a superior form? We cannot express by adequate terms, nor even by figures, things into which we do not penetrate. From the roots of a given number or figure, extract by means of the infinite calculus roots, one after another to the fourth or fifth power; or raise them four or five times to higher powers; then unfold or resolve the equation, or demonstrate it by figures or in numbers,—a thing you will certainly never attempt. And therefore that which is thus extracted or raised is not perceived as to its quality, but only as to the fact of its existence. *Wherefore, if they are expressed they appear as paradoxes, to wit: That this form or substance is simple, and relatively to all natural forms and substances, a unit void of figure, extension, magnitude, gravity, and levity, and therefore not material. That in it nothing can be said to be above or below, or to be carried to a centre, or a surface or along a diameter. But one and the same point in fluxion is seen to be set in the centre, in the radius, in any periphery whatsoever, and in a thousand simultaneously and successively.* If we reflect upon the nature of etherial modification whereby arises the sensation of sight we find an image or likeness of fluxions of this kind, that is, similar phenomena and paradoxes. For a ray springs forth from every point of the object or objects, and through the stream and myriads of rays flowing from other objects, it passes diametrically, obliquely, or in a straight line, in every direction; thus one and the same ray here represents a centre, elsewhere a circumference, and elsewhere again a diameter,—nay, many, both simultaneously and successively. "It is necessary (says Plato) that that which receives forms of all kinds should itself be void of all form." He calls this form "an invisible form void of figure and yet capable of all figures,—a form which is perceived with difficulty" (*Timaeus*, p. 50-51 in my copy*). He is speaking of what he calls the One, or what Leibnitz calls the Unit or Monad, and Wolff Simple Substance. Plato calls this One also the First and Smallest (*Parmenides,* p. 153), and by it he means the nature of simple substance (*Ibid,* p. 166). "The One (he says) is in itself void of magnitude and of smallness, and it neither exceeds itself nor is exceeded" (*Ibid,* p. 150). "The simple ens (says Wolff), has no parts; is not extended; is indivisible; is endowed with no figure; is void of size; can fill no space; in it no intrinsic motion is possible; to it can be attributed no properties that belong to a compound as such, that is, that are attributed to a compound by virtue of its definition" (*Ont.,* 673-679, 682-3). But to resume. That such an entity is void of gravity and levity is thus explained by Aristotle: "The heavy is that which is prone to be borne to the middle, the light that which is prone to be borne from the middle, the most heavy that which is gathered under all other bodies that are borne downwards. . . . Everything that is borne upwards or downwards has either levity or gravity. . . . A body that is borne in a circle cannot possibly have either gravity or levity, for in no case can such a body, either naturally or preternaturally, be moved to a centre or from a centre. Local motion in a straight line is not in accordance with nature herself, for it was said that there is one local motion of every simple body" (*De Coelo,* lib. I, cap. iii). He is here speaking of the simple body, which he places midway between the infinite and the compound body. "Every body must be either simple or compound, and therefore the infinite itself must be either simple or compound." (*Ibid,* lib. I, cap. v.) So likewise with us. For I call this form, or if you prefer, this substance, simple, because it is the first natural form; above it, is the infinite itself (as will be seen), and below it are compound forms or substances. Thus the divine essence which is above, is not to be called a simple form, since the name form is not suitable to it. This substance was called by ancient philosophers "the *prima materia,* which is moved with a motion that consists in receiving form;" and they said that "form is desired by it as eagerly as perfection is desired by that which is imperfect." That the wise spoke in this manner is related by the Philosopher in his SAPIENTIA DIVINA SECUNDUM AEGYPTIOS, lib. IV, cap. ii.

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*The copy referred to is Stephen's edition.

[266b] *Into this form flows the universe called heaven, that is, each solar or stellar vortex; likewise its larger and smaller volumes; and also its individual entities.* That I use the words volumes and individual entities, as though they were compounded of parts properly so called, arises from the fact that no other words offer themselves to me whereby the fluxions and determinations of this form, in that it is a form, may be expressed. We must therefore speak infra-naturally, but, as said above, we must be understood in an analogical way, or by way of eminence. "The reasoning (says Aristotle) is the same with respect to the whole and to the part. In a like way is it in agreement with reason," etc. (*De Coelo,* lib. I, cap. iii.) *For each such individual entity is an exemplar representative of its universe. Such is the internal form of each individual of the purest blood or first animal essence which runs through the simplest fibres; so that its form merits to be called celestial, for it draws its essence from the celestial ether or from primitive nature.* That this first substance arises proximately from those things in the universe whereon are impressed by the supreme deity the principles of natural things, and wherein, at the same time, lie the most perfect forces of nature, see Transaction I, n. 591, and Transaction II, n. 227. But to resume. *The phenomena that emerge from this aura or form, and reach our senses, are exceeding few; for they lie inmostly concealed in nature. Nevertheless the real existence of this form cannot be doubted; for without it there would be in the world neither vortical forms nor the forms succeeding thereto; neither, in the animal kingdom, could simple fibres have existence, nor those infinite marvels of nature which flow out from*

her inmost bosom and from the simple fibril and its purest essence, both immediately and mediately.

267. *The form superior to the celestial form, prior and more perfect, is the* PERPETUO-CELESTIAL, *properly to be called the* SPIRITUAL, *and most far removed from the ultimate or earthly form.* Philosophers, ancient and modern, and also theologians call spiritual essences forms, which inhabit the heavens even as we inhabit the earth;* in place of forms some substitute substance or power, and these they name spiritual substances or celestial powers. Therefore we do not transgress against accepted formulas of speech when, by way of eminence, I call the divine spirit spiritual form itself. For here, form and substance coincide, as will be seen in what follows. In relation to this form, angels also are called forms, such, for instance, as angelic forms; and our mind itself is said by the Philosopher to be the immortal and eternal form of forms [*De Anima,* lib. III, cap. v, viii]; by which he means the spiritual form. But angels and our souls cannot properly be styled spiritual forms, but rather more perfect celestial forms which, unlike those forms of which we have just treated, are created for the reception and influx of the spiritual form, to which also they are accommodated. Nevertheless they merit the name spirits, inasmuch as these forms, to wit, angelic forms and our souls, unlike the celestial forms of which the starry heavens consist, are images of the spiritual form; for they owe their operations to the spiritual form immediately, since, in themselves, they are inferior and posterior and are subject to the spiritual. But we shall see these points better illustrated in the following Transaction.† *Above all created nature, and therefore incomprehensible, ineffable, inexpressible by the most sublime analysis of the human mind, form in the abstract, contemplating all other forms in order outside itself and at the same time in itself, in that they are*

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*See 2 *E. A. K.* 356, where these theologians are mentioned by name; see also n. 269 below.

†The Transaction referred to is Transaction VI, on the Soul or Rational Psychology. See *Generation,* Acton's translation, Preface, p. 8.

perfect. For if we progress by a series like the one we have just instituted it follows that the spiritual form refers itself to the celestial, just as the latter refers itself to the vortical, and so on to the angular, which is the last in the order of respects and representations. Thus it can be said that this form contemplates other forms both as outside itself and as within itself,—but within itself, in that in their own degree they are most highly perfect; for nothing of imperfection can come forth from that which is most highly perfect. *With which the material, the extended, the fluid, and whatever is terminable in nature, and therefore accidents and modes, have no compatibility; thus neither the terms whereby material things are expressed,—except indeed by supereminence; for it is above all predicates. Thus a more abstract speech, which may be spiritual and angelic, or a more sublimated thought, must be used in expressing and determining the powers and essences of this form. Unless this form were flowing into the inferior forms the latter would neither exist, nor subsist, nor be moved, still less would they live, understand, and be wise. Thus this form is the principle of existence, subsistence, action, life, understanding, and wisdom.*

268. *But the perpetuo-spiritual form is the* DIVINE *form itself,—not properly a form, but pure essence, life, intelligence, wisdom, and most utterly abstracted from space, time, matter, figure, motion, change, destruction.* On these points there is a consensus of opinion among philosophers, including the ancients, such as Plato who approaches the subject as follows: "The One is infinite since it has neither beginning nor end? Yes, infinite.* . . . Therefore it is without figure, since it partakes neither of the round nor of the straight. . . .

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*This is the answer given by Parmenides to the question propounded by Socrates. The dialogue form of the original is not retained by our author in the rest of the quotation.

†We are unable to find this quotation in Plato. The nearest approach to it which occurs in the work cited is, "God, according to the ancient tradition, who holds the beginning and the end and the middle of all the things that are, proceeds directly to accomplishment according to his nature." (*De Leg.* lib. IV, p. 716.)

Nor can it be carried around in a circle" (*Parmenides*, p. 137, 138). *The creator of all things, the beginning and the end.* "There is a conviction in the souls of men (says Plato), that God is the commencement and the end of all things, and that his force and power efficaciously permeate all parts of the universe" (*De Legibus*, lib. IV†). "All things are full of the gods" (*Epinomis*, p. 991.) *Far above nature, and outside of which are all things.* "The infinite (says Aristotle) is not that outside of which is nothing, but that outside of which is always something." (*Naturalis Auscultatio*, lib. III, cap. ix.) Thus he wishes to make the world either coeval with the infinite, or else eternal. But he speaks according to the last acumen of his perception; for the intellect is not capable of penetrating beyond or above nature, thus into the eternal or infinite; therefore he does not discriminate the one from the other. But, being better enlightened by the Scriptures, we know that these two, namely the divine and the natural, are utterly distinct. For the rest, he affirms that all things are below God, yea, even the elements themselves or simple substances. "All philosophers unite in making subject to the infinite some nature or other of those things which are called elements" (*Natur. Auscul.*, lib. III, cap. iv). "The elements of material things are not matter, neither are they infinite" (*De Generatione*, lib. II, cap. v). "The element of bodies is that into which are divided all other bodies wherein it resides, either potentially or actually" (*De Coelo*, lib. III, cap. iii). *Thus incomprehensible. For in it is all that is perpetual, infinite, eternal, unlimited, holy; and it is the order, law, idea of the universe. This form inflows into celestial and angelic forms, and into our souls, by the mediation of the spiritual form and of the Word. But so many are the arcana, that it is better to be silent, to be lost in astonishment, to fear and adore, than to speak of this subject in a way not holy, that is to say, naturally.* Compare Transaction I, n. 296-298, and Transaction II, n. 265-268.

269. *In addition to the natural forms of the universe or world recited above, first among which is the celestial form, there are also other forms which are called vital and therefore* *also spiritual, such as angelic forms, and human souls and minds, as also the souls of brutes.* For these forms are called spirits not only by philosophers but also by theologians,—both by the Fathers such as Augustine and others, and by their disciples;* and this because they are partakers of life and likenesses of intelligence. *These are posterior to the verimost spiritual form, inferior and more imperfect; and therefore they are without and below it, that is, are subject to it. These forms are created for and accommodated to, not only the beginning of motion but also the reception of life and intelligence by means of influx from the spiritual form.* This point has been treated of at length in Transaction II, n. 241-272, and therefore I refrain from treating of it again. *On which account they are images and likenesses of its operations, and therefore are called spiritual forms. These forms descend into the ultimate world, and ascend therefrom, by a similar ladder and in a similar series as the forms mentioned above which are purely natural and, in consequence, relatively dead,—being neither participant of life and sensation still less of intelligence, nor capable thereof.* The manner in which they ascend and descend has also been copiously demonstrated in Transaction II, n. 272-291, and elsewhere throughout; for this is the very subject of our Transactions. *And in respect to essential determinations and fluxions, they in every way emulate the forms of the universe or world, and so correspond to them that the one flows into the other in the most highly suitable manner. For instance, angular forms into the sensories of taste and smell; the circular or modificatory form of the air, into the sensory of the ear; the spiral or modificatory form of the ether into the sensory of sight or into the eye, and so on.* Compare Transaction II, n. 288-291, and elsewhere. *So the spiritual form flows into the soul itself which is formed for the reception of its divine operation, whence arises its principle of life, and intelligence.* [Transaction II, n. 292.] For which reason I have ventured to style the soul or its substance the supereminent organ in its body. Compare Transaction II, n. 275. *Thus from the forms of nature, we learn the quality of*

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*See above n. 267, note.

the forms of life, the series of which forms is represented in the animal kingdom alone as in its microcosm.

270. *In addition to the forms of the universe or world, and the forms of life, there are also forms of the vegetable kingdom and forms of the mineral kingdom; of all which forms there are genera and species, and genera more or less perfect and imperfect, and so likewise species. There are no other forms but forms of the world, forms of the animal kingdom, forms of the vegetable kingdom and also of the mineral. The forms of the three kingdoms are dependent on the forms of the world and correspond to them. Thus, from the forms of the world we learn the quality of the forms of its kingdoms, and the manner in which the spiritual form flows into them immediately or mediately, to the end that all things may flow constantly from an end, through ends, to an end, in provident order.* Compare Transaction II, n. 267, 268.

271. *Such is the ascent of forms from the lower to the higher; nor is this ascent merely an ascent of forms, but it is also an ascent of substances, forces, modes, qualities, and accidents,—none of which would exist without forms. When we thus raise ourselves from inferior forms to superior, we are said to ascend into a superior, prior, more universal, simpler, purer, and more perfect nature, sphere, potency, world, aura or ether; nay, to superior heavens; but there is a higher and a lower region in each sphere.* For we talk of a higher and highest region of the atmosphere or air and also of a lower and lowest; and how far soever we ascend into this, we are still in the sphere of air. So also in the case of the other auras. Therefore a region cannot be said to be prior and more universal. *In each degree, when forms are carried up by this ladder, something earthly, material, and finite is cut away and put off, and a certain celestial, perpetual, and infinite is superadded and put on.* The perpetual and infinite in the circular form is the circle itself, since it lacks beginning and end; but there still remain in it semidiameters or radii, which, since they terminate in some centre, are finite. This finite is put off in the spiral form, since the radii of this form terminate in some circular surface which is of infinite fluxion.

But since what is finite still remains, by virtue of the fact that the spiral in this surface is determined into another form of motion, therefore in the superior form this finite is put off, and the looking to a centre or point of rest, together with what is linear, recedes ever farther away. *Until at last nothing except what is perpetual, infinite, eternal, pure, holy, that is, divine remains.* "It is evident (says the Philosopher) that that which is first of bodies is perpetual, and neither increases nor decreases, grows old nor is subject to alterations or passions (*De Coelo,* lib. I, cap. iii). "God first created the supreme world in which, without any thought, he set up forms all pure and perfect,—such, namely, as are procreated with their essence without affections. Afterwards he created this world that falls under our senses as an image of the former." (*De Sap. Div. sec. Aeg.,* lib. XIV, cap. vii.)

272. *We have striven towards these principles by the analytical way; from them, thus searched out, that is to say, from things first, let us now descend by the synthetic way to things postreme or lowest. For in order that we may arrive at principles which may be so many truths, it is necessary that we strive thither from things posterior, that is, from experience in the region of effects.* But let us not make a leap to things supreme without paving the way by matters of experience, for then we may readily seize upon falsities as truths. To strive from things posterior to things prior is called the analytical way or method, while to descend from thing prior to things posterior is called the synthetic way or method. The analytical is to us, since the fall, the natural way; for we arrive at none of the sciences except by sensual experience which is made up of a totality of observed phenomena and modes; and therefore also we are long in acquiring wise judgment. The mind so depends on the experience of its senses that it hardly dares to reason unless it is supported by experimental proofs, and when these are lacking, it stands as it were impotent and knows not whither to turn. *In the same order then it follows that from the Divine proceeds the spiritual, from the spiritual is created the celestial, from the celestial is produced and flows the vortical, from the vortical the spiral, from the* *spiral the circular, and from the circular the angular. Thus by a long series of succession and derivation, or by six degrees, there is produced from the most perfect that which, in itself and its own nature, is more or less imperfect, although in that* is not in itself imperfect because it does not approach to the *sphere nothing more perfect than itself can exist.* A thing perfection of the prior; but in its own degree it can be most highly perfect. For example a brute animal or the soul of brutes may in itself be most highly perfect, although it does not approach to the perfection of man and his soul. In itself the circle is perfect, despite the fact that the spiral is more perfect than the circle,—for it is necessary that what follows in the order of derivation should be relatively imperfect. "In nature (says the Philosopher), the perfect precedes the imperfect; from which considerations it is clear that in the nature of things there is in a body some substance other than those constituents of bodies which we find around us, more divine than them all and prior to them." (*De Coelo,* lib. I, cap. ii.) "In nature are implanted the principles of generation." (*Sap. Div. sec. Aeg.,* lib. VII, cap. iii.) "[The *prima materia* exists by motion which is perfect action]. It is comprehended by the thought as being according to an infinite vicissitude of change from one form into another, nor does it obtain the place of a principle (or beginning) except only by the reception of form." (*Ibid,* lib. IV, cap. ii.) That nothing imperfect was created by God, nor can be created, is dictated by Sacred Scripture, and by sound reason; and this is true of man, of the solar system, and of our earth. *But that forms most perfect in their own degree become in themselves more or less imperfect, that is, are changed essentially.* I do not mean forms of the world which are void of life, but forms of the animal kingdom, that is, souls, and also angelic forms, all which are endowed with liberty of action. From the change of the more perfect state of these forms into one that is more imperfect flows also a change of the elements, nay, of the earth itself,—a truth which may be abundantly confirmed and which Sacred Scripture itself teaches. *This comes from causes without and below, and thus from causes within themselves, but not from causes above* *themselves. For if a form, in itself and its own nature more imperfect than a higher form and more perfect than a lower, seeks and yearns to become of the same quality as the superior form, or of the same quality as the inferior, then it necessarily undergoes essential change; and then the forms which have their descent and generation from it take on a similar and still greater imperfection according as they are distant from their origin.*

273. *In order that we may represent to ourselves an idea of the generation and derivation of such forms, or, of one from another, it is necessary that we hold to the idea of the existence of the superior forms within the several inferior, and at the same time to the idea of accidental changes; for the perfection of higher forms consists in the undergoing of accidental changes.* What accidental change is and what essential change has been explained above* [n. 241]. *Therefore when a number of superior forms unanimously associate together, and enter into, determine, and constitute one form which is then called a substance per se, there comes into existence a proximately lower form; and when these latter forms similarly associate together and enter into one form, there comes into existence a form still lower, and so on in order.* I speak of a number of forms associating together into one, just as though there were in superior forms plurality or quantity, and spatial relations, so that they can approach nearer, associate together, and be distinguished from others. But, seeing that form is an essential determination, and such determination cannot be conceived of without fluxion, nor fluxion without the idea of something that is determined,—whether it be a point, or a likeness of points, or anything whatever that is something,—therefore we cannot abstract the idea from a representation of plurality. Otherwise we should perceive nothing. In default of words in the higher spheres which shall correspond to words in the lower spheres, recurrence must be had to words of which we have some notion. Let us suppose then, that a particle of air is a kind of minute bladder, or, for the sake of a better understanding, let us take [a particle of] aqueous vapor. Suppose this to be distended by a small volume of air, and each particle of the air by a small volume of ether, and each particle of this by a small volume of higher ether; thus [the particle of aqueous vapor] by so many forms each in due order more simple than the other. It then follows that one form is generated from the other, and that the vapor or the aqueous bulla is the complex of them all, and that in it exist all forms from the first natural form to the last. Then, if the form of fluxion of the higher ether be vortical, it follows as a consequence that the fluxion of the ether within the bulla, is spiral, while that of the air is circular. But this will be better learned from a consideration of the fibres. *Wherefore when a compound form is dissolved it reverts to the prior form.* "All natural things (says Aristotle), have within themselves a certain order in which one depends on the other. In this order that which is posterior, when it perishes, reverts to that which is next among things first, until it is brought back to the celestial orbs." (*Sap. Div. sec. Aeg.*, lib. XIII, cap. viii.) *Thus one form flows into the other, and that which is prior is always more internal, and that which is posterior always more external, and hence more remote. Thus the first form is* toto coelo *distant from the last, though inmostly residing in it. Hence it follows, that in the compound there is nothing substantial save that first and one which is called simple substance.* "In the compound ens (says Wolff), there is nothing substantial save simple entities." (*Ontologia,* p. 792.) "There are no substances save simple substances, and compound entities are aggregates of substances" (p. 793). *And that veriest force perpetually impressed, which resides therein.* "If there is force in a compound substance (says the same illustrious author), it must result from the forces of simple substances" (*Ont.*, 795). "Being, (says Plato), is distributed throughout the whole multitude of things, and from not one of all the things that are, either the smallest or the greatest, is it absent; moreover, in every single part of being is present the One (that is, simple substance, the unit or monad), which is absent from no part, whether small or large." (*Parmenides,* p. 144.) "Compounds (says Aristotle), are moved at the nod of the simple which is within them dominating and overruling." (*De Coelo,* lib. I, cap. ii.) "The first moving must necessarily move itself; which motion it undergoes according to nature; and the things which are moved, not being quiescent in their place by force, must necessarily establish that order which they now observe." (*Ibid,* lib. III, cap. ii.) "A simple body must of its own nature be fitted to be borne in a circular motion; that such a motion be the first motion is a necessity." (*Ibid,* lib. I, cap. ii.) *Such is the ingeneration and such the generation of forms or substances compounded from their simples. But that inferior forms may not fall asunder, but may subsist, and the superior flow into them, it is necessary that they be also distinct and that each one form and occupy its own sphere, to wit, the more perfect forms the superior sphere, and the more imperfect the inferior; in such way, however, that superior forms shall ever be present in inferior, and not the reverse.* "To God is given the highest and first seat of the world (says the Philosopher). That body most greatly feels his force and enjoys his divinity, which is situated next to him; then that which holds the second position, and each body thereafter according to the order of positions constituted by nature, all the way to our position." (*De Mundo,* c. vi.) *For which reason it is impossible that there be any vacuum.*

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*The author here adds "in the present chapter."

[273a] *From these considerations it now follows that posterior forms may undergo essential changes, while the prior forms still remain permanent in their integrity, except that these enter into accidental changes, and by reason of this, are as it were absent, although they are most fully present just as before, but not with the same power and force.* For if the generation be such as has been described it follows that the inmost forms may nevertheless remain permanent in the integrity of their essence even though the external determinations, or the determinations of the exteriors, be changed. Take, for instance, the aerial bulla or bladder spoken of above, which is of the circular form. If this should be changed into an elliptical form it would not prevent the interior bullæ from being able to retain the determinations of their own fluxion; for a change in the compound does not

penetrate to those more simple forms so that they likewise are changed. They do not indeed then flow according to their whole nature; for in the ellipse they must regard two centres, and not one as in the circle. Therefore, by their accidental changes they accommodate themselves, to wit, that they may mutually regard each other through variations of expansion or contraction, and thus may associate together. This assuredly in no way changes their essence, although their force of operating according to all their potency is diminished. Thus, in the triangle, wherein are perpetual oppositions of determinations, they may be said to be deprived of their fluxion, but not therefore of their endeavor to action. *But to treat of these matters briefly is to treat of them obscurely; it suffices, however, for the intelligent.*" Let us now return to our fibre.

CHAPTER XVII.

THAT THE SIMPLE FIBRE IS OF A CELESTIAL NATURE.

274. *Before we gird ourselves for a treatment of the simple fibre, let us premise the universal rule of the derivation of forms.* The nature of the series in the derivation of forms has been explained just above, n. 273, but I have not reduced it to a universal rule. *Namely, That the form of parts, individuals, substances, or units in themselves, is always superior to the form of the volume, or of the parts, or of such units among themselves.* They are called parts when they are endowed with figure and size; but when elevated to superior nature, they put off the qualities of figure, and are no longer called parts but simple substances or units,—as they are called also by philosophers, ancient and modern; in other respects they may also be called individuals. Meanwhile, that the form of the individual is prior to the form of the volume of the parts, and superior and more perfect, has been shown above, n. 273. For the compound cannot but be posterior to and more imperfect than its components which are simpler and purer; and, therefore, when a compound is resolved it relapses into a superior or more perfect sphere of nature. *Or, that we come to a superior form only by the division or destruction of the* *part or unit, and to an inferior form only by the gathering together of such parts, that is, by composition.* That there is no ascent from the substance of an inferior degree to the substance of a superior except by the division or destruction of the unit, see Transactions I, n. 158-161, and II, n. 222, 290. *Thus is it in the macrocosm or in the world, and thus in the microcosm or in the animal body.*

275. *From these considerations it follows that if the form of the blood vessels be circular, then the form of the medullary or nerve fibres is spiral, and the form of the simple fibre is vortical; and, finally, that the form of the individuals, substances or units which raise up* and determine the simple fibre,* (see n. 254), *is celestial. Thus fibres are elevated in due order from the next to the last all the way to the very first form of nature. For blood vessels are compounded of nerve fibres, nerve fibres are raised up by the simple fibre, and the simple fibre is determined by its individuals which are so many simple substances.* Compare above, n. 257, 258, 259. The origin and derivation of blood vessels from fibres will be dealt with in a special chapter [n. 298 *seq.*]. This is the case not only in the composition of fibres, but also everywhere else in the body, as, for instance, in the great heart. This heart is simply expanded and constricted, like a circular form; but its constituent parts, or the motor fibres extended from the upper edge of the base obliquely, downwards, and crosswise, at last wind around after the manner of gradual spirals. So also in the brain, where the cortical substances, led around into intestinal tracts as it were, perpetually go and return into harmonies (*numeros*) and gyres emulating those of the spiral. The medulla spinalis also winds its fibres into similar gyres; whereby it comes to pass that their reciprocal motions carried on with ease and without any sense of resistance, do not cease until they themselves cease to live. That nature has transcribed its whole power of action into the spiral fluxion is clear from things obvious to the sense, as for instance from the screw; for the more gradually the spirals or oblique grooves of a screw are raised above the horizontal plane, the more do resistance diminish, weights disappear, and inert forces become elevated more nearly to the active, nay, the spontaneous forces of nature. What then would not be the case in forms perpetuo-spiral or vortical? and what not in celestial forms? Is there not in these the beginning of the spontaneity of nature?

**Excitare,* the word here and elsewhere translated "raise up" might, with equal correctness, be rendered "rouse up" or "excite." Both meanings are involved, for that which raises up or constructs its organ or receptacle, also rouses up or excites that organ to action, *i. e.,* vivifies it.

276. *Such is the mutual ingeneration and composition of fibres and vessels in the animal body, and such is the derivation of forms; but in order to their subsistence, it is necessary that they be also distinct, that is to say, that posterior forms, or vessels, form and occupy their own sphere, and prior forms, or fibres, theirs.* See above, n. 273, and Transaction I, n. 602, 603. *Therefore they are allotted places in such way that ultimate fibres or blood vessels hold and infill the body proper and its provinces, medullary fibres the cerebrum and cerebellum, and simple fibres the cortical substance itself, which resides in the supreme place.* The cortical glands which are the origins of the fibres are woven of none other than simple fibres, as is shown in Transaction II. *Thus, comparing the body with the lowest sphere, or with the sublunary region, its heaven is the brain divided into orbs and hemispheres, while in the higher place or above heaven resides the cortical substance which pours out its fibres like rays through the brain into the universal body.*

277. *Thus the microcosm or animal world is likened to the macrocosm or universe, wherein are spheres celestial, sublunary, and terrestrial. The likeness also lies in the fact that the sphere which holds the supreme position or which represents heaven is also within and most fully present in all the inferior spheres. Thus the cerebrum and more especially the cortical substance which is the common sensory and motory of all parts of the body is present everywhere in the inferior spheres; and it not only contemplates them but also governs them at its nod and will; and if it were not most fully* *present among them by means of fibres, the several parts in the kingdom, together with their wholes, would come to ruin.*

278. *But in the cortical substance, or inmostly in the supreme heaven, the soul which partakes of the divine essence, has, like a deity, fixed her abode. For from this substance and by means of it, she discerns and disposes the several things in her world and system, and in each of them she provides that order shall be observed. To her, therefore, within her kingdom, is assigned a certain species of omnipresence, power, knowledge and providence.* Compare Transaction I, n. 258, 259. That she has also formed and, as it were, created all things, see *ibid,* n. 253 *seq.*

279. *Since then the simple fibre is produced immediately from substances of a celestial form, it follows that it is not of a terrestrial nature, but far removed from terrestrial forms; having its origin in the purest ether, or in heaven;*—contrary to the sentiment of Aristotle and the peripatetic school, who calls the fibre earthly; but, Oh, how far removed it is from this! *Placed at the height or summit of nature so that it may almost be called nature herself in her first infancy, it is that in which is the principle of natural forces, conatuses and motions, and from which all other forces flow.* See what was said above (n. 266) with regard to the celestial form, with which the present points coincide. *Its qualities cannot be expressed in words,—qualities which, if they should be expressd, would appear like paradoxes, to wit: That it consists of simple substances, as of so many units or monads, which are void of figure, extension, size, gravity, and levity, and hence are not material; and, That they are so many exemplars representative of their universe or microcosm; that is, that in themselves they contain in potency everything in the universal corporeal system which, after formation, comes under the senses and becomes apparent.* All these particulars may be seen explained in the preceding chapter on Forms. *From such forms, natures, or heavens, is raised up and determined the simple fibre from which are all compound fibres.*

CHAPTER XVIII.

THAT THE SIMPLE FIBRE IS FROM SUBSTANCES OF A SPIRITUAL NATURE, AND THUS IS PARTAKER OF LIFE.

280. *In addition to forms purely natural, or of the world, there are also forms which are partakers of life and intelligence. These likewise are superior and inferior, prior and posterior, thus more or less perfect and imperfect. All are subject to the verimost spiritual form, for they are created for the reception of its life and intelligence and are accommodated thereto. Wherefore they are images or likenesses of its operations; and therefore they also are called spiritual forms.* These points may be seen better explained above, n. 269, and in Transaction II, chapter iii [n. 231-239 On the Human Soul].

281. *Of this kind are those first forms in subjects of the animal kingdom,—superior and more perfect in men, inferior and more or less imperfect in other animals, and most imperfect in insects. These forms, in like manner as forms purely natural, descend by order of derivation and by a successive series, even to the ultimate world; and suitably to their nature, they construct and create the microcosm which is called their body. For they are exemplars representative of their universe, and contain, as it were in a type, whatever afterwards comes to view in the constructed body.* On these points compare the whole of chapter iii, Transaction I, [n. 241 *seq.*] On the Formation of the Chick in the Egg. *Fibres are the determinations of their forces, and, at the same time, are rays of intellectual light,—fibres which they send forth from the brain as from their heaven, and by the mediation whereof they act and sensate. Thus these forms may be called so many powers, lives, and intelligences.*

282. *These forms, because they are entities of primitive nature, and are the beginnings of the forces, conatuses, and motions in their own system, and depend immediately upon the spiritual form and its influx, can be no other than those celestial forms of which we have already treated, and which* *raise up and determine the simple fibre. For if they were superior to celestial forms they would be above nature and in like degree with the divine spiritual form. Therefore, because they are these same celestial forms, the fibres raised up by them are consorts of life.*

283. *Now, in that the fibre is from substances of a spiritual nature and is thus itself partaker of life, it follows that the medullary fibres also, in their own manner, are living. For in the medullary or compound fibre there is nothing substantial save the simple fibre; therefore, in that fibre there is a more common, that is, a more obscure life. This is the reason why every modification of the ether or air, as soon as it strikes a sensory organ constructed of fibres, begins to live, and is called sensation.*

284. *Posterior or more imperfect forms of this kind, which are the first forms of other animals, are also created for the beginning of motion and at the same time for the reception of life.* Although they are posterior, nevertheless the spiritual form flows into them immediately; scarcely otherwise, if we may use the comparison, than as solar light flows both into objects or substances which are more simple and into those which are more compounded. But the more simple they are, in that they are more perfect, the better and the more distinctly do they receive it, and the more singly do they apply its virtue and goodness to themselves. See Transaction II, n. 261-265. *But they are inferior forms, and are compeers to those which we have styled vortical. Wherefore many of them are, as it were, living magnets which, of themselves and their own nature, know the quarters of the world.* That to the vortical form are due the marvellous phenomena occurring around the magnet, see above n. 265 [b], and further, in Transaction II, n. 338-347. *Nor are they capable of receiving superior life, that is, intelligence, still less wisdom; for they are as distant from man as is the vortical form from the celestial.*

CHAPTER XIX.

THAT THE SIMPLE FIBRE IN ITS BODY IS ANIMATED PRINCIPALLY;* OR, THAT IT FLOWS FROM THE SOUL IMMEDIATELY, AND IS OF ITS SUBSTANCE.

285. In this chapter I have appointed to treat briefly of the soul and its nature and essence. But what the soul is, and what its nature, is a subject which does not suffer itself to be delivered in a few words, nor in bare words, without illustration from examples and philosophical axioms, and without the authority of the learned,—an authority which, to human minds not so far refined as to penetrate with minute exactness in determining whether those things which sound like truth and are said to be such, are really true, brings much light because much faith. That I may satisfy the reader in these matters, I have decided to enter upon a special treatise on the commerce of the soul and body, and on its state in the body and also after the death of the body; and at the same time to bring forward the opinions of the learned, and to set forth in what way they are consentient and dissentient.† Here I could do no other than put forward, as by way of preface, such things as are seen to conduce to an illustration of the point that this celestial and spiritual form, of which I have treated in the preceding pages, is the same as the soul. Wherefore, essences and intelligences such as human souls are, are frequently called by philosophers, nay, and by theologians, forms, such as angelic forms, spiritual forms.

286. *The universal body is animate; otherwise it would neither be, nor live. For that in the body which is, and that which lives, is the soul. The body without the soul neither ex-*

**Principaliter*, from *principium.* The meaning is that the simple fibre is animated from firsts.

†This promise was fulfilled at any rate in part, in the work on the SOUL or RATIONAL PSYCHOLOGY; see the author's preface to that work. See also the little work on THE SOUL AND THE HARMONY OF SOUL AND BODY, in Posthumous Tracts; this was written soon after the work on the FIBRE, occurring in the same MS. volume towards the end. An earlier treatise on the same subject is translated in SCIENTIFIC AND PHILOSOPHICAL TREATISES, PART II.

ists nor subsists nor moves; but the soul without the body both exists and subsists and also acts; for the soul is the beginning of its body, and also its representative exemplar; therefore the body is the type, image, simulacrum of the operations of its soul.

287. *There is nothing existent in the universal world, nothing in the threefold kingdom of the world, animal, vegetable and mineral, yea, neither is there any society, nor action, nor utterance and speech, within which is not its own soul.* Wherefore, unless we dispose the several parts according to the form of the soul itself, which is the essence of the things that follow, we are diverted from the path of nature. So also, unless things that exist are perceived as being correspondent to their soul, we do not penetrate within the surface of things, nor to their very kernel or marrow. *And that is the soul of a thing which is first, which is in seconds, which is the universal regnant in thirds, and to which everything owes the fact that it is such as it is. That which, according to the order of nature, has been made such as it is, that is, has been formed by the soul, is called its body, and this is the more perfect in the degree that it is a type, image and simulacrum like to its soul. Therefore, he who calls the soul into doubt, necessarily calls into doubt the existence of every single body, and of every thing that exists in the world; for the corporeal structure and form is from the soul, and is the ultimate image of its forces and operations. By reason of this, the soul is the form of forms of its body.*

288. *Therefore none can be so insane as to deny the existence of the soul, unless he wishes to deny his own existence and that of all the things which are within him and which are without him. Now because there is nothing existent in the created universe which has not its own and proprial soul, the enquiry to be made is, not whether the soul is, but what is its nature in each subject. It is from form that the soul is such as it is, and that it is of this or that genus or species.* By soul we ordinarily understand that,—either in ourselves or in brutes,—which is, that is to say, which lives. But there are souls of every existing thing, both in the vegetable kingdom and in the mineral and in the universal world; or, everything, especially in compounds, that has any existence from things prior [has its own soul]; for the soul is that which is first in them and reigns universally, and without which they would not exist. Wherefore, in familiar discourse, we say that such and such is the soul of society, the soul of speech, the soul of action. And because there are so many genera and species of compounds in each kingdom, nay, in those things which are called accidents and modes, therefore, the soul is not living except in the animal kingdom. The soul of angular forms is the triangle, for this it is that dominates in all forms of this class and degree; nor is it really the triangle, but the essential determination or the form of the triangle, which makes it to be such as it is, that is to say, inert, and not of itself suited for any motion. So also in other cases. *That substance in a subject which is the first substance that has such form within it, is said to be its soul; which substance is therefore called simple substance, the one, or the unit or monad.*

289. *In order, therefore, that it may be known what the human soul is and what its nature, recourse must be had to form itself. According to what has been said, this form, as to nature, is celestial, and as to life, is spiritual, simple, void of part, size, extense, figure, motion, gravity, and levity, not corporeal nor material.*

290. *But because there is no form without determination, and because no determination can be conceived of without fluxion, and no fluxion without the idea of part, extense, figure, motion and matter, therefore these several properties are to be represented as though they were within,—but by analogy or eminence; for what therein is essentially determined, whence arises the form, is not nothing, but is something. But, by elevation from power to power and thus by degrees, everything which partakes of figure, motion, and matter, puts off that which has held it finited and limited.* For when forms are carried up by their ladder, at each step something earthy, material, and finite is cut away and put off, and a certain celestial, perpetual and infinite is superadded and put on; see above, n. 271. *And thus puts off the very terms whereby finite* *things are represented. But words are required, if such there be, within which is a perpetual and infinite such as is within superior forms; but then one must speak angelically and spiritually, or, during this life, must think abstractly, that is, in respect to such matters, must speak by analogy and eminence.*

291. *From these considerations it now follows that the soul is the same as simple substance within which is celestial and spiritual form; and hence that it is the same as those forms of which we have just now treated. From these forms, as from so many simple substances, is raised up and determined the simple fibre. Wherefore this fibre flows immediately from the soul, and thus in its corporeal system is animated principally, that is to say, is endowed with a celestial nature and a spiritual nature. Thus the simple fibres are so many rays of the intellectual light of the soul, and determinations of its conatuses and forces, that is, of its will.*

CHAPTER XX.*

THAT THE UNIVERSAL SIMPLE FIBRE IS RAISED UP FROM FORMS OF A CELESTIAL AND SPIRITUAL NATURE.

292. *It is necessary that the simple fibre also be transpirable, pervious or gifted with an exceedingly minute cavity, and thus be an idea or image in least effigy of its compound. Otherwise neither itself nor anything whatever in the body which is animated by it, could derive and carry on its origin, progression, order, law, motor force, and sensation. Wherefore, the simple fibre without a perfluent analogue of a fluid would be a thread or line impotent of action.* Confer, n. 253.

293. *Because in the simple fibre there is the likeness of a cavity and the likeness of a surface such as exists in compound fibres, it follows that those most perfect forms or substances by which that fibre is raised up and determined, put on such a state that there are things which represent a surface and things*

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*Several of the principles laid down in chapters xx-xxvi, are briefly presented in the opening paragraphs of the RATIONAL PSYCHOLOGY, n. 1-14.

which represent a fluid running through the cavity. In order that they may put on this state they must undergo accidental changes whereby they are rendered more or less active and more or less susceptible of life. What an accidental change is and what an essential, I have explained above [n. 241], namely, that an accidental change consists in their being able to be rendered more ample or more constricted while the form remains ever the same; as, for instance, if the circle become larger or smaller, still the essence of the circle is not then changed, but it is rendered more or less active. *And thus they maintain such an order that the likeness of a surface and the likeness of a cavity is formed in the simple fibres. For the perfection of superior or more simple forms consists in their faculty of undergoing accidental changes.*

CHAPTER XXI.

THAT THE SIMPLE FIBRE IS NOT SOLID, BUT APPROACHES RATHER TO THE NATURE OF A FLUID.

294. *The simple fibre, consisting of forms most pure, most active, and at the same time living, cannot but be in perpetual fluxion, that is to say, be determined by the fluxion of its substances. For the sole thing that induces rest on such substances is their determination according to a form other than that which is proper and natural to them,—and in the simple fibre this is not possible.* As for instance, in the angular figure; for in this figure, they are able to be determined, not according to their own nature or form, because not into the circular or spiral or vortical form, but to an infinite number of centers which do not conspire to a form perpetually mobile; and because there are perpetual oppositions and collisions there arises rest and inertia. It is otherwise in the simple fibre wherein there is left to them entire liberty of fluxion.

295. *What in itself and its own nature is fluid precedes what is solid; for in order that a solid may exist, subsist, and be moved at the nod of its simple, it must be determined and formed by a fluid and according to the nature of a fluid. Thus every solid must in its infancy have been fluid. The simple* *fibre is ever in its infancy and flower of youth, because all other fibres and vessels,—and thus the universal body,—perpetually exist, subsist, move, and live by means of it. Therefore, if the simple fibre were solid it would be impotent of action, and this would be the veriest death of the whole system.* That every solid in its primordial periods has been soft, yea, fluid, is a statement which I know not whether anyone can justly deny. For a solid consists of parts, and indeed of the minutest parts, which were not capable by their own means of coalescing into a mass. Still less was this possible in the animal body where the tunics of the vessels and fibres correspond in the minutest respects to the fluids running through them. In the first formation in the egg or in the womb all things are so delicately soft that there is not the least consistency; in time they grow together, and in old age they harden, whence comes rest, cold and death.

296. *Nor is it any objection that the nerve, which is a congeries of fibres compounded by degrees from the simple fibre, is more or less soft or hard, and is coherent. For, as the nerve is resolved into its principles, so its solidity decreases and the fluidity of its constituent parts increases. The somewhat hard consistency of the nerve is also contributed to by the humors which run through the medullary fibres, and through the interstices of the fibres, and also through the interstices of the fascicles,—humors which are impregnated with saline and sulphureous corpuscles as with so many forms that are angular and are gifted with the force of inertia.* Confer chapter x, [n. 188 *seq.*].

297. *Anatomy itself also clearly demonstrates that the nearer fibres come to their origins or cortical substances the more tender and soft they are, nay, that at the least touch, they melt away into a droplet; so that in themselves and their own nature, the fibres are quite soft, so far as sense and touch reaches. What then is not the case with simple fibres which are set above our sense and touch? It follows, therefore, that the simple fibre is not solid and hard, as many have opined.* Such as Aristotle, who asserts that the fibre is not only earthly but also solid, and from him the peripatetic school and also many of our contemporary philosophers; and, moreover, some medical men, whose prince, however, Hippocrates, says that there is nothing existent in the animal body which is not transpirable and conspirable. Leeuwenhoek makes frequent mention of a humor which was seen to result from disruptured fibres flowing together into a droplet, in the following words: "Moreover, I saw that many small vessels had degenerated into an aqueous matter," (n. 22); and elsewhere, "Certain vessels had flowed together into an aqueous matter," [n. 23]. This could not have happened unless they had been almost fluid. It is a fact in the light of experience that the beginnings of nerves, in the brains, are quite soft, although the nerves arising therefrom are more firmly, because more compactly, consistent,—a fact which is also mentioned by almost all anatomists; see Willis, n. 8, and Bartholin, n. 14. Nay, according to the observation of Ruysch, a certain mucous is visible under the pia mater covering the cerebellum, from which flow down still softer stamens. What then is not the case in insects, which themselves are, as it were, a delicate humor? An essence such as that which flashes through the simple fibre and excites it, when flowing is then in the circle of its nature and is borne whither its soul determines it. But howsoever it acts in its fluxion, there are in it, nevertheless, degrees of fluidity with the utmost distinctness, and these correspond with each other; as is the case, in things visible, with the solid and the soft, and the soft and the fluid. For an essence of this kind can take on every ratio of variation that is possible in the universe; hence arise harmonies.

CHAPTER XXII.

THAT FROM SIMPLE FIBRES ARISE MEDULLARY OR NERVE FIBRES, AND FROM THESE BLOOD VESSELS.

298. *There are simple fibres, compound fibres, which we call medullary or nerve fibres.* From the description of the fibres in what follows, it will more clearly appear what simple fibres are, and what compound. Those are called compound which compose the nerve fascicle. This fascicle is not a fibre further compounded, but it is an aggregate of fibres. Those fibres which we have called compound are the same as those seen by Leeuwenhoek through the microscope and shown delineated in his figures. For the sake of distinguishing them from simple fibres, we call them nervous or medullary, because they are the principal constituents of the structure of the nerve and of the medulla of the brain. *And there are blood vessels, or arteries and veins. From the simple fibre is formed the compound or nerve fibre; from the nerve fibre, both immediately and mediately, the blood vessel. Thus the simple fibre is the first fibre, the medullary fibre is the second or middle fibre, and the blood vessel is the third or ultimate fibre. By reason of this, fibres may also be called vessels; that is to say, the first fibre is the simplest vessel, the second fibre the middle vessel, and the artery and vein the vessel proper, or the blood vessel. Thus there are three degrees of fibres or vessels.* This is the reason why anatomists indiscriminately call fibres vessels and vessels fibres; for the word vessel denotes a minute canal through which circulates a fluid. *Besides these, there are also fibres of a middle nature, or corporeal fibres, of which we treat elsewhere.* Respecting these see above, chapter ix [n. 188, *seq.*], and in the following Transaction on the Animal Spirit.*

299. *As fibres or vessels descend by a threefold degree of composition, so also do the fluids or humors which run through those fibres or vessels. Through the simple or first fibre flashes that essence, truly animal, which we have said to be the very substance of the soul.* See chapter xxi, [n. 294 *seq.*]. *Through the medullary or middle fibre flows the second or middle animal essence which is called the animal spirit.* Respecting which, see the following or fourth Transaction. *Through the ultimate fibre, or the arterial and venous vessel, runs the red blood. These essences or fluids mutually succeed each other in the same order as do the fibres themselves.* See these points treated in detail in Transactions I and II, consult Transaction II,, n. 222, where the passages are referred to. *Thus all of*

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*See n. 242, note.

them may be called animal or vital essences, and also all of them may be called bloods, yea, all of them may be called the souls of their own world. That the blood is the corporeal soul, see Transaction I, n. 46. Therefore also Sacred Scripture affirms that the soul of brutes resides in their blood. Scripture also makes mention of bloods; as for instance, that the bloods of Abel cry for vengeance [Gen. iv. 10], and elsewhere frequently. *For the one descends from the other, and the posterior is the vicegerent of the prior; thus the red blood is the soul's vicegerent in the body or in the ultimate sphere of its world. But now to the several fibres in order.*

300. *The simple fibre, even from its first origin in the cortical gland which it has woven, sinuously flashes like a ray, toward the ultimate points of the body; and by a wonderful circumvolution or form, which I have called the vortical, it raises up a little canal which is the medullary or middle fibre. Thus this latter is a mere membrane formed by the circumgyrations of the simple fibre. This medullary fibre derives its form of fluxion, which is simply spiral, from the vortical fluxion of its simple fibre,—according to the law of order in the derivation of forms.* See the general rule of derivation in n. 274; and for the manner in which one form flows in order from another, and the spiral from the vortical; and also that the form of fluxion of the nerve fibre is spiral, see chapter xvi [n. 255 *seq.*, especially n. 258].

301. *The medullary or nerve fibre, by a similar mode of circumgyration, raises up and conglomerates delicate canals which are least blood vessels, or arterial and venous capillaries; thus these vessels also are mere membranes formed by the winding of the medullary fibre.* The reader may see the demonstration of these points in Transaction I, n. 146-154. But in that place I made no mention of the simple fibre, but only of exsanguinous vessels, that is, vessels which carry the middle or white blood, or that blood which is called the animal spirit. Therefore, the passage cited should here be further illustrated; but this cannot well be done except in the following Transaction where I have appointed to treat of the Animal Spirit, and also of the Corporeal Fibre. Meanwhile the reader will see it there illustrated that the blood vessel must take its origin from nerve fibres. *These vessels derive their form which is simply circular, from the spiral fluxion of the medullary fibre,—according to the law of order in the derivation of forms;* n. 274, and chapter xvi, [n. 255 *seq.*].

302. *From these fibres, that is, from the simple and compound fibre and the blood vessel, is produced everything which exists in the universal body. For there is nothing existent in any gland, muscle, sensory organ, and viscus except this threefold fibre most distinctly formed and woven with all variety. So also in the tunics of the larger arteries and veins, wherein is found nothing but a complexity of fibre and vessel.*

303. *The tunics of the larger arteries are five in number. The first or outmost of these is nervous on the outer surface and vascular on the inner.* According to Boerhaave, see Transaction I, n. 126. Moreover there are innumerable nerves which flow into the trunks of the arteries and veins; such, for instance, as the intercostal, flowing into the branches of the azygos,—and into the azygos itself and the vena cava,—into the aorta, and also into the internal carotid and everywhere else; upon which arteries they creep like ivy and then betake themselves towards the inner parts. So also over the pulmonary vessels, around which the fibres flow in the manner of a spiral. This is so obvious that there is not room even for doubt. So also they flow into the surface of the heart and its muscle; see Transaction I, chapter vii, On the Motion of the Adult Heart, [n. 460 *seq.*]; and this so evidently that, from the very determination of the nerve fibres, one may be allowed to judge as to the nature of the motion, or of the determination of the motion, of the heart and also of its arteries. In the macerated muscle of the heart Lancisi found nothing but fibres and blood vessels [Trans, I, n. 463]. The cause of muscular motion can be evidently deduced from the influx of the fibres into the blood vessels, and I know not whether it can be deduced from any other source. *The second is cellular and is also called glandular,* according to Heister and Boerhaave, Transaction I, n. 120, 126, and elsewhere. *The third is tendinous; the fourth muscular, contextured of a great number of an-*

nular fibres; the fifth or inmost is a membranous tunic, by some called also a nervous. Confer Heister, Transaction I, n. 120, and Boerhaave, n. 126. *These five membranes are formed solely of fibres and vessels diversely woven together. From the first membrane, which is nervous and at the same time vascular, is produced the second or glandular; from this again the tendinous, made up of so many emissaries or ducts of the glands; and, finally, from this, the muscular. Thus are blood vessels raised up by the medullary fibres, both immediately and mediately; and thus in the animal microcosm as in the macrocosm, do forms mutually succeed each other.* Respecting the tunics of the arteries and their derivation confer the whole of chapter II of the first Transaction [n. 116 *seq.*].

CHAPTER XXIII.

THE FORMS OF THE ANIMAL KINGDOM AND THEIR SUCCESSION OR DERIVATION BY THE MEDIATION OF FIBRES AND VESSELS.

304. *Forms in the animal kingdom are as many as are forms in the universal world, which latter have already been treated of; nor do they differ in the nature of their fluxion. Hence they also are celestial, vortical, spiral, circular, and finally rectilinear or angular. But because they have in addition this property, namely, that they are living, these forms are called vital, and the first of them spiritual, but the rest organic. But that one form may be derived from the other and be procreated by it, there must be fibres, first simple, then compound or medullary, and finally blood vessels, which are so many essential determinations.*

305. *The first form, which is also the first form of nature and the first form of the life of this kingdom, is a celestial and spiritual form, properly the soul which is simple substance having this form within it. This also is the eminently organic form, and merits to be called the eminent organ of its body.* Transaction II, n. 275. *For it is the form of all the other forms of its microcosm; for the others, outside itself and like itself, as being derived from itself or to be derived, it contemplates as present in itself.* The spiritual form is the soul; but the primitive cortices are of a celestial form.

306. *The second form is the cortical and cineritious substance in the cerebrum, cerebellum, medulla oblongata and medulla spinalis, which is essentially determined by the first form or by its substances, by means of simple fibres. Hence it comes about that this form is vortical; and because the simple fibre is living,* chapter xix, xx [n. 285 *seq.*] *this form is intellectual. For within it is the faculty of perceiving, understanding, judging, and willing,—a property which it draws from its soul which is a spiritual form and is intelligence. This is the first organic form, or the first of the organic forms that follow.* See the whole of chapters II and III [On the Cortical Substance of the Brain, and On the Human Soul], in Transaction II [n. 69 *seq.*].

307. *The third form is the whole cerebrum taken in a broad sense, which is determined by the second form, or by its cortical substances, by means of medullary fibres. Hence it comes about that this form is spiral.* For the whole cerebrum is circumvoluted and drawn into spirals; so also the medulla spinalis; and especially the fibres issuing from these two. *And because the medullary fibre is living.* For the entire second or medullary fibre exists from the first or simple fibre (chapter xxii), and thus lives a life not so distinct as the simple fibre but more obscure. *It is inferior to the intellectual form, and is properly to be called the sensitive form. For within it is the faculty of perceiving the things which come in from the external organs of the senses, and also of imagining and desiring.* For understanding and sensing, thinking and imagining, willing and desiring, mutually correspond to each other, as the power of a superior form to the power of an inferior form,—as will be seen in the treatise on Correspondences.* *Which property it draws from its intellectual form. This is*

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*See the little work "Introduction to Rational Psychology. Part Second, On the doctrine of Correspondences and Representations" (3 Photo. MSS., p. 183 *seq.*). As its title implies, this is evidently the work promised in the text. It was followed by "A Hieroglyphic Key of Natural and Spiritual Arcana, by Way of Representations and Correspondences," which was published after the author's death.

the second organic form,—if the spiritual form or soul is taken as being above all.

308. *The fourth form is the heart, taken in a broad sense or together with the arteries and veins, which is determined by the third form or by the brain by means of blood vessels. Hence it comes about that this form is circular.* Blood vessels cannot properly be said to arise from the heart, though after they have arisen they flow into the heart; but they are raised up by nerve fibres, in accordance with the points which were brought forward in the preceding chapter. This was also observed by Malpighi in the incubated chick, namely, that the blood vessels do not at once reach their little heart, but first stand around and approach it gradually. It is evident also from the circumstance that the little heart, circumvoluted with fibres, comes into existence after the brain. Therefore the brain rouses to action the blood vessels and the heart itself, and in the muscles determines them absolutely. Confer Transaction I, chapter iii, [On the Formation of the Chick in the Egg, etc., n. 241 *seq*]. *And because the blood vessel is living, though it lives a more obscure life.* The reason is, because it consists of mere simple fibres. Wherefore also the schoolmen set the seat of the soul in the heart, and believed, at the same time, that the sensory fibres were produced therefrom. *This form is properly to be called the animal form; for within the heart and its arteries is the faculty of acting, and, obscurely, of sensating.* Transaction I, n. 231, 232, 233. *A property which it draws from the brain.* For whatever is animated is living, and therefore also the blood vessels,—but in their own degree.

309. *The fifth form is the whole body, taken in a broad sense, which is determined by the fourth form, or by the heart, by means of motor fibres. Hence it comes about that this form is rectilinear and angular, such as it is in muscles, tendons, cartilages, and bones. And because the motor fibre lives in acting and acts in living, this form is properly to be called the corporeal form. For within the body and its members, viscera, and motor organs is action,—a property which it draws from its heart. This is the ultimate form, or the complement of forms, which corresponds to the first form in the soul.*

310. *Thus in the animal kingdom there are existent forms prior and posterior, and one succeeds the other and is derived from it; that is to say, from the spiritual form the intellectual, from the intellectual the sensitive, from the sensitive the animal, and from the animal the corporeal. Each prior form holds and embraces in itself all posterior forms in potency; and each posterior form the prior in actuality. Such is the succession and derivation of forms in the animal kingdom; which possess this property above purely natural forms, that while acting naturally they also at the same time live spiritually, and so receive their name from their better quality.*

311. *Simple fibres are the essential determinations of the soul; compound or medullary fibres are the essential determinations of the cortical substance; nerves and fascicles of nerves, the essential determinations of the brain; blood vessels, of the heart; and motor fibres, of the body; for of these are made up the members and viscera.*

312. *Simple fibres are those by means whereof the soul modifies itself for the formation of its organic machine. Second or medullary fibres are those by means whereof the rational. mind modifies itself in order that it may act out what it judges, concludes and wills. Nerves and fascicles of nerves are those by means whereof the cerebrum modifies itself in order that the desires of its animus may be determined. Blood vessels are those by means whereof the heart determines itself in order that the things which superior forms regard, will, and desire may follow on to the effect. Motor fibres are those whereby are moved entire members and viscera which are the ultimate effects, whence come acts.*

313. *Simple fibres are determined and modified by the vortical form of fluxion; compound fibres by the spiral form of fluxion; blood vessels by the circular; and motor fibres by the linear.* But as regards nerves and fascicles of nerves, these are not determinants but aggregates of determinants.

CHAPTER XXIV.

THAT THE UNIVERSAL FORM OF THE BODY, BOTH INTERNAL AND EXTERNAL, CONSISTS OF SIMPLE FIBRE ALONE.

314. *If by the simple fibre is raised up the compound or nerve fibre, and by the nerve fibre the blood vessel; and if in the body there is nothing except fibres and blood vessels, which compose the whole of organic forms; it follows that it is nothing else than the simple fibre which constructs the form of the body both internal and external. Thus there is nothing truly substantial in the whole body save the simple fibre, and nothing in the simple fibre save the substance of the soul. Tendinous, cartilaginous, and bony structures also consisted, in their first infancy, of nothing but vessels and fibres, as is confirmed by the anatomy of the chick in the egg and of the embryo in the womb.* Lancisi, in his treatise ON THE HEART, proves that the tendinous matter of the heart consists of muscular fibres closely united together. [Transaction I, n. 464.] That a muscular structure hardens into a tendinous substance, this into a cartilaginous, and this again into a bony, is evident enough; also that the cranium itself was once a membrane yielding and soft; and so also the other bones, which are soft before they are hard, and fluid before they are soft. The umbilical vessels and the ductus arteriosus of the heart are changed in time into tendons; so also many other vessels, which are deprived of their blood and stopped up with a humor of alien kind.

315. *The fluids that run through the fibres and vessels, and through the ducts constructed by these, are so many rivulets which make their passage and accomplish their circles within their little canals; but it is the canals themselves, constructed of the simple fibre, that shape the form, to which latter the fluids thus contribute no more than to sustain it.* It appears as though some vessels or filaments were compaginated also of terrestrial matter; but this is caused solely by humors impregnated with terrestrial particles, which stop up those canals, and make it to appear as though the canals themselves were fabricated of terrestrial matter; as is the case in the bones, which when burned give off a urinous odor, and when boiled pass off into jelly. Nay, this is the case even with the vessels and ducts of the tunics; hence it comes about that we think the tunic itself to be of this nature.

316. *If the simple fibre be by nature celestial and spiritual, and if it be the essential determination of the soul itself, it follows that the form of the body both internal and external, is from a celestial and spiritual origin; and is the soul in ultimates.*

CHAPTER XXV.

WHAT THE SOUL PROPERLY IS, AND WHAT THE BODY.

317. *The soul is the purest animal essence, celestial and spiritual, which raises up and modifies the simple fibre, and at the same time enters into the blood both white and red. All its individuals are most perfect, first, supreme, most simple forms immediately subject to the divine spiritual form, and created for the reception and influx of its operations. These forms, which therefore are lives and intelligences, are the soul. And because this constructs the whole animal form such as we behold it with our eyes, therefore the whole of it is in every part, and it is the one only substantial which reigns and lives in this whole system.*

318. *But what is the body? There are strictly earthly parts, such as saline, sulphureous, oily, aqueous, and others, drawn from the mineral and vegetable kingdoms, and also from the bosom of the atmospheres, which are within the red and white blood and the other humors arising from the blood, and which surround the blood. These are angular forms, inert, cold, dead, heavy, material and corporeal, and they are those veriest forms which constitute that which is called the body; nor do they contribute anything whatever to its form except that the soul can thus and in no other way, descend from its heaven and dwell upon the earth.*

CHAPTER XXVI.

THE CIRCULATION OF THE RED BLOOD, THE PURER BLOOD, AND THE PUREST THROUGH VESSELS AND FIBRES; THAT IS, THE CIRCLE OF LIFE WHEREBY IS CARRIED ON THE COMMERCE OF SOUL AND BODY.

319. *At every turn of the circulation the red blood or the globules thereof, is resolved into the purer blood; and this again, or the globules thereof, into the purest; and passing through the fibres, it is again compounded; and so on.* The resolution of the red blood has been treated of above, n. 199, 200. [For the rest, see] Transaction II. n. 117-31, 165, 222, Transaction I, n. 92-96, 100, 148, 149, 150, 158-160, 371, 649. Meanwhile I wish here to add something more, since it is of importance that we be convinced of these matters; for in order that the one circulation may be continued into the other, it is necessary* that the blood be twice and a third time resolved. It is a known fact that the softer and better blood is withdrawn towards the brains, and that the viler is rejected, and this towards the liver, whence comes the bilious matter. That the blood is better when it is softer more flexible and more divisible, is confirmed by Leeuwenhoek,—who is convinced of the fact from many experiments,—in the following words: "I saw that blood globules could be elongated, and could come out the more flexible in proportion as the blood was more healthy; that is to say, that they could be reduced into a longish figure, or one that was three times longer than their thickness." He observed that when he was ill the globules appeared harder and firmer, but that when he enjoyed better health, as they became softer and more fluid, so they were better consociated with each other; from which he infers that death follows from ther hardness, Transaction I, n. 29. He states moreover, that he has frequently observed their resolution, see above, n. 200; and that when they were subjected to a distillatory fire, they were actually resolved into spirits and oils. Reason also gives her support; for it is beyond all doubt, that the blood is not only born, but is also unborn and reborn, that it may be fit for distinctly entering into and passing through the medullary fibres in the brain, and for producing in the corporeal system all that is conducive to its continuation and sustenance. The arteries and vessels themselves are split up into lesser vessels, and, finally, by the medium of the cortex, into fibres; otherwise they would be entirely destitute of perfluent juice, either being obstructed, or else being wounded with perpetual aneurisms.* If the blood were not opened up it could not be the storehouse and seminary of all things in its body, since, in order that it may put anything forth from itself, it is necessary that it open its bosoms and enclose that thing. Its being able to give does not come from the serum, for the serum exists for the sake of the blood. To the end that the blood may be thus often compounded and recompounded there is need of daily aliments, of an afflux of chyle, yea, also of a purer food drawn from the circumfluent air and ether. But why should I recount the several points? The things which confirm are innumerable, nay, they include also the phenomena of the several diseases.

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*The Latin is "ne necessum est ut sanguis," etc. The "ne" here is meaningless. It is probably the beginning of the word "ne-cessum," the author inadvertently commencing the word over again.

320. *Thus there is a distinct circulation of the red blood; a distinct circulation of the purer blood, that is, of our animal spirits; and a distinct circulation of the purest blood, that is, of the essence of our soul; just as there are distinct vessels, namely, arteries and veins; distinct medullary fibres or nerves; and distinct simple fibres. Thus there are three circulations, as there are three bloods or animal fluids; and there are three fibres or vessels.*

321. *The first circulation, like that fibre which is simple and that blood which is purest, is the most simple, the supreme,*

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*Blancard's Medical Dictionary (edition of 1777) speaks of two kinds of aneurism, the true and the false. The *true* consists in a tumor resulting from the rupture of the inner or outer coat of an artery and the consequent dilatation of the other coats; but the *false* consists in a rupture of all the coats, and the consequent escape of the blood. The latter appears to be the aneurism referred to in the text.

inmost, most remote and most perfect of all; the one only circulation which reigns in the rest and over the rest; of which can be fitly predicated whatever has been predicated of the simple fibre and of its substances and forms; for it is these same substances and forms that carry on this circle.

322. *The second circulation, like that fibre which is medullary and that blood which is purer, follows just after the first circulation, and comes just before the third circulation. Thus it is mediate, and is more simple than the following circulation, superior to it, more internal, more remote and more perfect; but less simple than the preceding circulation, inferior to it, posterior, more external and more imperfect; of which can be fitly predicated all that has been predicated of the medullary or nerve fibre, and all that has been predicated of the purer blood or animal spirit; for it is this same animal spirit that carries on this circle.*

323. *The third circulation, like the ultimate fibre or the blood vessel, and like the red blood itself, follows just after the second circulation. Thus it is the last of the three circulations, the outmost, postreme, and compound; and it is more imperfect than the two prior circulations, and is the corporeal circulation itself; in which and over which reign the two others; and of which can be fitly predicated all that has been predicated of the artery and vein and of the red blood; for it is this same blood that carries on this circle.* Respecting these circulations confer Transaction I, n. 148, 325-344, 359-370.

324. *The other humors, which are compounded of the blood and its purer essences and saline elements, and of the serum, also perform their circulations; for there is no animal humor existent which does not circulate after its own manner.* See Transaction I, n. 148. *But these circulations are special and particular, and they depend on that of the blood, while the three circulations mentioned above, are the determinants of all things in their kingdom. Wherefore the first is a superior universal circulation, the second an inferior universal circulation, and the third, or that of the blood, a general circulation.* What the superior and inferior universal is, and what the general, see Transaction II, n. 205.

325. *As the simple fibre enters into and excites the medullary or nerve fibre,* chapter xxii, *so the first circulation the second. Or, as the first animal essence, which is its soul, enters into and determines the second or middle essence, which is the animal spirit,* Transaction I, n. 37, 40, 41, 91, 97, 110, 503, 556, 634, 656, and in the Transaction on the Animal Spirit, *so the first circulation the second.*

326. *As the compound or medullary fibre enters into and composes the blood vessel,* chapter xxii, *so the second circulation the third. Or, as the animal spirit enters into and determines the red blood, so the second circulation the third. Thus whatever has been said of fibres and vessels and of their fluids, may fitly be said of their circulations. For the circulation indicates what is the form of the fluxion in fluids and in their fibres or vessels, and what the nature of the form; and also the reverse.*

327. *Each circulation is carried on separately; all are also carried on conjointly, that is to say, the first in the second, and the first and second together in the third or blood circulation. This influx of the one into the other is what we call the circle of life.* Respecting this circle see our first reflections in Transaction II, n. 168-171. *And if this circle be rightly explored, then will be understood the nature of the mutual and reciprocal commerce of soul and body. For the first circulation is that of the soul.* The word circulation does indeed involve local motion, and yet the soul is void of extense and motion, n. 289; but because the determination of the soul is along the simple fibres, and determination without fluxion cannot be conceived of, therefore, for the sake of a better understanding, in place of determination, I have used the word circulation, although this word is not altogether adequate except by way of correspondence and by analogy; confer n. 290. *The third circulation is that of the blood, or is the corporeal circulation, n. 323; and the middle is that of the animal spirits, by means whereof the soul inflows into the body, and harmony is established between them.*

PART II.

THE ARACHNOID TUNIC.

THE ARACHNOID TUNIC.

[FROM EXPERIENCE.]

328. The arachnoid tunic, a name borrowed from Arachne,* whose web or fineness it imitates, adds itself to the upper surface of the pia mater, and like a second layer of the latter, is transmitted with it into the several external tracts and hiatuses, depressed, elevated or evenly plane, but does not enter the furrows and ridges. On this account, when it is removed, the nature of the cerebrum and particularly of the cerebellum, as being discriminated into circles, becomes evident. It invests the subjacent mater more closely in the upper part of the cerebrum and more loosely below, and above the cerebellum; more strictly in the eminences of the medulla oblongata, more laxly in the depressions; more tenaciously in the anterior portion of the medulla spinalis, and more freely in its posterior portion where it is suspended by the decurrent denticulate ligament. It also restrains the nerves in their beginnings.

329. RIDLEY (*Anatomia Cerebri*). It was the opinion of the old anatomists that the pia mater was the only other integument of the cerebrum, and that it was a single integument. This was admitted as being the plain truth equally by two somewhat recent anatomists, the learned investigators Willis and Vieussens, and by all the newer writers, if we except Bidloo and Bohn, each of whom claims to have found,—the one three hours after death, and the other fifteen days after,—another distinct cerebral integument stretched between the external covering or dura mater, and this inner covering or pia mater. Both these anatomists took this integument to be the origin of the

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*Arachne was a mortal maiden celebrated for her skill in the most delicate weaving. Being deeply hurt as a result of a contest with Athene, her teacher, she hung herself and was afterwards changed by Athene into a spider,—Greek *arachne*.

second integument proper to the medulla spinalis. Vieussens, however, supposes it to be a duplicature of the pia mater confined to this region. But the existence of an intermediate membrane in some parts of the brain, especially at the base of the cerebellum whence it is continued downwards into the medulla spinalis, and which constitutes the second integument proper to that medulla, has now been lately observed by myself,—though whether it is a separate membrane absolutely distinct from the subjacent membrane which famous authors style the pia mater proper, and which is common to the medulla spinalis and the brain, as also is this second intermediate membrane; or whether it is one and the same membrane doubled so as to consist of two layers, is a matter respecting which one may certainly entertain doubt. That I might, therefore, satisfy myself in respect to this difficulty, I instituted an examination with the utmost possible accuracy. This examination was made on a highly dropsical human brain, wherein consequently was no cavity nor any interstice that was not reached by the extravasated water. Thus wherever in the natural construction of the parts, there was a duplicature of this membrane more loose than ordinary,—such as are found at the extremity of the calamus scriptorius between the superincumbent cerebellum and the medulla spinalis; in the isthmus or space set between the cerebrum and cerebellum; over the processes called nates and testes; in the deeper part of the cerebrum between the beginning of the annular process and the first appearance or projection of the olfactory nerve, (as observed by Vesalius, who called it the process of the pia mater), there was found a large quantity of water which distended such duplicature far beyond its natural limits (Ed. *Lugd. Bat.*, 1725, p. 12). In my subject I found this membrane entire, and free from any division throughout its whole circumference, with the exception of the regions mentioned above. But, supposing that there was a similar formation in this membrane as is found in the membranes of other parts, I endeavored to divide it. This was done with happy success in a number of its parts; but much more easily in the beginning of the superficial folds of the cortical part of the cerebrum, where minute interstices exist naturally, between which creep many blood vessels to immerse themselves into its cortical and medullary parts (p. 15). Moreover this duplicature most manifestly communicates with all the nerves both within and without the cranium, constituting by its outer layer their second integument under the first, which latter is taken from the dura mater all the way to the whole fascicle of nerves; and by its inner layer their third integument which supplies an envelope or covering to the several simple fibrils which, taken collectively, compose the whole body proper of the nerve. It is by means of the stupendous delicacy of this membrane investing these medullary fibrils, which of themselves are all insensible, that there is brought about so prompt a consensus between part and part, and between all the parts and the cerebrum itself (p. 20).

330. WINSLOW (*Exposition Anatomique*). The two layers of the pia mater are not so firmly coherent as those of the grosser mater. The arachnoid or upper layer is not continuous with the lower except by means of a cellular tissue which accompanies their whole common extension excepting in certain places at the base of the brain, etc., where the inner layer continues its insertions* while the outer is spread evenly over the more raised parts, and in the intervals between the said parts is entirely separated from the inner layer without any intervening cellular tissue. By reason of this ability to separate in a number of places, the upper layer has been considered as an outer or third envelope distinct from the pia mater, and called the arachnoid. This web or cellular tissue accompanies not only the common extension of the two layers but also the particular extension of the inner layer in all its duplicatures and septa, as can be best exhibited to the sight by inflation (*Traite de la Teste,* n. 51, 52). If merely a little opening be made in the outer layer above the lobes of the cerebellum,† and by this opening the cellular tissues be inflated, it will be seen that by means of the inflation the two membranes are gradually separated; and at the same time will come to view the beautiful ordination of the membranous

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*So Winslow; but Swedenborg has "expansiones" *expansions.*

†Thus Winslow; but Swedenborg has "cerebrum."

septa or duplicatures of the inner layer and the multitudinous distribution of blood vessels winding therein. Especially will this be seen after a successful anatomical injection, or when the membranes are in a state of inflammation (*Ibid.* n. 101).

331. The arachnoid membrane is seen to be most distinctly separated from the pia meninx in the interval between all the eminences of the inferior surface of the medulla oblongata, except that between the two layers is noted cellular tissue. The internal layer, or pia mater, adheres more frequently to the surface of the intervals than to that of the eminences; but the external is as though lifted up by the eminences and stretched out evenly between the parts receding therefrom to which it is firmly united (*Ibid.* n. 116). In the medulla spinalis this membrane is more distinctly separated from its internal meninx, so that by inflation it can be elevated from one end to the other, when it presents the appearance of an intestine; but the inner layer is firmly agglutinated to the medulla and sends into it many septa and productions. If air be forced through a hole made in this pia meninx, it raises the surface on the opposite side, and separates it on the inside from the subjacent medulla (*Ibid.* n. 188). The arachnoid membrane also accompanies the separate fascicles of the nerves all the way from their origin to their passage [from the cranium], and forms a species of interrupted duplicature between the little cords which creep through the dura mater (*Ibid.* n. 158). It adheres to the pia mater* more firmly below than above, and, in a manner, is suspended by the denticulate ligament which rules all along the two sides of the medulla (*Ibid.* n. 129).

332. HEISTER (*Compendium Anatomicum*). In the upper part of the cerebrum the arachnoid tunic is so closely adherent to the pia mater that it cannot be separated therefrom without laceration; but in the lower part, especially around the cerebellum, the medulla oblongata, and the whole of the spinalis, it is so loosely connected that it can be easily seen. Like the dura mater, the arachnoid is extended through the whole of the brain and medulla spinalis, as can be seen if it is suspended in water or spirit of wine. It has no blood vessels. In appearance it is like a spider's web (n. 268). In the medulla spinalis anteriorly it is closely conjoined to the pia mater, while posteriorly it floats, as it were, freely (n. 273).

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*So Winslow; but Swedenborg has "dura mater."

333. A delineation of this membrane may be frequently seen in anatomical works. Bidloo shows it separated from the pia meninx and laid back. He says that it is whitish, and he exhibits it as furnished with minute blood vessels; as coarser than the fine meninx [pia mater], and finer than the coarse [dura mater]; as found in all the gyrations of the brain. See particularly Ruysch's delineation, where the membrane is shown separated by inflation from the subjacent meninx. In this delineation also are seen the sulci or anfractuosities covered by both layers, with the result that their depth is obliterated; and also the most minute portions of the same membrane elevated by the inflation simultaneously with the other and lower membrane. Vessels of the utmost minuteness, (says Ruysch, in the description of his table), are brought to view by the inflation, and they derive their origin, not only from the aforesaid inflation, but also from a watery moisture which lodges between the membrane in question and the pia mater. [*Epistolæ* ix].

334. RUYSCH (*Epistolae*). I confess myself beset with many difficulties in the matter of delineating the arachnoid membrane; for it is so subtle, and in so many places closely attached by fibrous connections to the subjacent pia mater and its blood vessels, that by no possible skill can the whole of it be separated uninjured, especially in the place where it invests both hemispheres of the cerebrum on the upper surface under the dura mater. In various places it is indeed elevated by air forced in through a little tube, but it at once subsides and disappears. Anyone, therefore, can conclude without much trouble as to the difficulty, nay the impossibility of delineating it in an uninjured condition. In the region of the cerebellum, however, and especially in the posterior part, and also in the region of the medulla spinalis, it is very easily separated from the other envelope by inflation. This arachnoid membrane has the peculiarity,—never before observed by me either in the coarse mater or in the pia mater,—that not only is it so subtle a membrane that there is none more subtle in the body, (for which reason also its first finders, Blasius, Sladus, Suida, Swammerdam, etc., adorned this membrane with the name Arachnoid), but, moreover, that when by inflation it is disjoined from the subjacent mater in innumerable places, it takes on the appearance of a cellular membrane, especially in the membranes of the cerebrum which are beset by copious humor; and yet it is not at all cellular. Moreover it is not likely that fat, which I have sometimes found under the dura mater, has lodgment in this arachnoid tunic; since in the upper part of the cerebrum it is possessed by extremely few arterioles, if indeed by any. But fat, I think, adheres only in the pia mater. As to the presence of arterioles, they have never come to my sight. I confess indeed that sometimes certain vessels have been seen dispersed through it in the region where it invests the medulla spinalis, from which circumstance one may conjecture that it also enjoys its own blood vessels in the region where it involves the upper part of the cerebrum. But to construct vessels by conjecture is, I esteem, a very different matter from showing them, and, indeed, having them depicted as Bidloo has done. The blood vessels scattered through the pia meninx do indeed perforate this arachnoid tunic in innumerable places, but I have never been able to observe any ramifications communicated to it in the region of the anterior hemispheres of the cerebrum. Indeed I have frequently been deceived by these blood vessels scattered through the pia mater which have the appearance of running also through the arachnoid; but on deeper inspection I have detected my error. Do not believe either that this tunic is so gross as Bidloo's table, already referred to, indicates; for, as I have said, I do not find a more subtle tunic in the whole body (*Epis.* ix).

[**334a.** NUCK (*Adenographia Curiosa*). But you ask, Do lymphatic vessels occur in the cerebrum? Although some of our more recent authors, who have been very liberal in describing them, concede and readily admit their existence, yet, as I frequently observe, they form systems in their own brain, and make up viscera at their own pleasure. For when called upon for experiments they are able to show nothing out of the common. To speak frankly I have never as yet been able to touch the mark in this part. Meanwhile I think it cannot be denied that lymphatics have sometimes been seen in one or other part of the cerebrum, and not long ago a close friend of mine, an anatomist, informed me, "I have seen a lymphatic vessel in a cow's brain which should be well worth your examining to learn its origin and insertion. Not far from the pineal gland, from which perhaps it gets branches, it lies on the choroid plexus extending to the side of the infundibulum." Two years ago I saw a lymphatic going from the pineal gland just as from other glands. Thus it is indeed quite certain that the brain also has its aqueous streamlets, but they have not yet been brought distinctly to light (Ed. *Lugd. Bat.*, 1696, p. 149)].

335. I have put this little Transaction on the Arachnoid Tunic immediately after the preceding Transaction on the Fibre, for the reason that it is the arachnoid tunic which derives the moisture expressed from the meningeal vessels to the spaces between the fibres and between the layers of fascicles. For it has been shown that throughout its whole extension the nerve is like a filter or a perforated cane, in order that it may transmit distinct juices by distinct paths. This juice separates the junctures of the fibres and the layers of the fascicles and anoints them and lubricates the paths. Nor do I think that anyone can call into doubt the permeability of such fluid through the many-apertured structure of the nerve, if he gives even slight attention to the numerous phenomena of fluid nature, all which indicate that a humor whether aqueous or oily is carried through invisible passages easily and almost spontaneously from the lowest region to the higher, and in every direction obliquely; as is the case in stalks, branches, leaves and grasses, where it is carried from the roots to the very top; so likewise between marbles and other smooth and closely united bodies, provided only there be something bibulous placed between them, such as blotting paper, a moist bladder, (*vesica madens*), some sheath-like membrane; so also through the threads of cotton cloth; through ashes, salts, sugars; and even through rocks, plates of selenite and spar, metalliferous veins; nay, even through gold, and all other materials, as shown by experience. A glass goblet half full of a salt solution or salt water and exposed to the sun or to dry air, in the course of a few days is encrusted, both within and without to the very bottom, with a dense salt and crystal, through whose ordinately arranged pores the water on the salt-encrusted side creeps up, and, on the outside, down, and circulates,—as I have often seen by experiment. Little vegetable seeds thrown on the moistened sides of an earthen or clay vessel take root as in their own soil, and the outside of the vessel grows green and leafy if only water be kept in the vessel which shall contantly filter through. Since such phenomena obtain in the mineral and vegetable kingdoms, what not then in the animal kingdom where exist so many animating principles! so many tortile motory spirals, or tiniest presses! a fluid highly elastic, expansile, contractile, of the most perfect form, and moreover, threads formed after the whole nature of such fluid! Such an organic and motor machine, while it lives and flourishes, acts and is acted upon, cannot but transmit with discrimination the several kinds of essences, and after transmitting, distinctly reunite them. But now to the tunic itself.

CHAPTER I.

THAT THE ARACHNOID TUNIC IS CONTINUED THROUGH THE WHOLE OF THE CEREBRUM, CEREBELLUM, MEDULLA OBLONGATA, AND MEDULLA SPINALIS.

336. *The arachnoid tunic is the upper layer of the pia meninx, and is so distinct therefrom that by injection and inflation they can be separated.* The case is not like that of the upper layer of the dura mater which is united to the lower by intervening fibrous vessels. It is different with the arachnoid; for although in certain places it is conjoined to the lower layer by ligaments and septa, yet it frequently stands off for entire spaces. Therefore, it can be elevated by inflation, as in the cerebrum, according to Ruysch's experiment, n. 333, 334; and in the cerebellum and medulla spinalis, according to Winslow, n. 330 and 331,—which authors the reader may consult for himself. *It is spread over the pia meninx everywhere on the surface, but not where the pia enters into the folds and anfractuosities, and doubles itself.*

337. *The arachnoid is extended over the whole cerebrum from its very top to its last borders; and from there it is continued into the medulla oblongata, and from this into the medulla spinalis; nor does it cease except in the last apex of the cone where cease also the other meninges. It passes from the cerebrum into the medulla oblongata from the lower part and from the upper part. From the lower, it passes over the annular protuberance,*—as was observed by Ridley (n. 329 *supra*) in a dropsical brain. His words are, "There is a looser duplicature of this membrane in the deeper part of the cerebrum, between the beginning of the annular process and the first appearance or projection of the olfactory nerves (as observed by Vesalius who called it the process of the pia mater) where was found a large quantity of water." *From the upper, it passes around the testes or through the isthmus, which is the tract mediate between the cerebrum and cerebellum where are situated the testes, the nates and the pineal gland.* This also is according to Ridley and the other authors. This path is laid down from the cerebrum to the medulla oblongata, and here also is the path of its fibres. That it leads from the isthmus and over the nates, confer Ridley, n. 329, above.

338. *It is extended also over the whole cerebellum, and in like manner is continued therefrom to the medulla oblongata, and from the latter to the medulla spinalis. It passes from the cerebellum to the medulla oblongata also from two sides,—from the lower, to the annular protuberance, and from the upper, around the fourth ventricle, and, in fact, through the peduncle and the vermicular process which is the common node and gathering up of the circles of the cerebellum.* Such also is the continuation of the pia meninx which it accompanies; and so also do the fibres proceed. That it flows down from the cerebellum towards the fourth ventricle or towards the lowest part thereof which is called the calamus scriptorius, is mentioned by Ridley and also by the other authors enumerated above.

339. *Thus the arachnoid tunic extended over the cerebrum, is conjoined in the medulla oblongata with that which is extended over the cerebellum; and from the two sources it coalesces into one membrane, and, thus united, flows down through* *the great foramen of the occiput, and over the whole medulla spinalis, constituting the second integument proper to the latter.* According to Vieussens, who is cited by the other authors, though Vieussens mentions a third integument proper to the spinalis.

340. *From the above considerations it is clear that this tunic is a perpetual and continuous membrane throughout the whole encephalon, being in this respect different from the pia meninx and also from the dura; these are indeed continuous, but with an interruption by folds and insinuations. For the pia mater connects the several parts in particular, while the arachnoid tunic connects the same parts in general.* It does not insinuate itself with the pia mater into the anfractuosities and furrows, but is extended over them. Thus it does not enter into the cerebrum or cerebellum, but is entirely superficial; for when it is removed, the cerebrum and cerebellum appear bare with all their anfractuosities and sulci. Confer Winslow, n. 330.

341. *Thus the pia mater is a superior universal membrane, the arachnoid an inferior universal membrane, and the dura mater a general membrane; for the latter does not dip down into the several parts, but forms processes,—called processes of the dura mater,—only around the larger sinuses.*

CHAPTER II.

THAT THE ARACHNOID TUNIC ENCLOSES A LYMPH OF THE MOST CHASTENED NATURE.

342. *Since the arachnoid tunic is separable from the subjacent meninx, both by injection and by inflation, and in dropsical brains has actually been seen separated, it follows that there is an interfluent humor which keeps them apart; otherwise they would coalesce.*

343. *The pia meninx perpetually exudes a certain dew.* I wish to adduce entire the remarks of Pacchioni respecting the perpetual exudation of the pia meninx, in order that it may be clear that this meninx is itself a perpetual spring of humor.

His words are: "After you have carefully cut away the cranium and turned over, from the forehead to the occiput or to either side, a not inconsiderable portion of the dura mater in such way that the stronger cohesions of the two meninges still remain; and then shortly afterwards have wiped off the dew of the meningeal substance, you will see new drops coming from the substance, and the same kind of moisture, and this even without any pressure of the finger,—a most sure proof, not only that the pia meninx is for some reason externally pervious and perforated, but also that in its foramina or punctures trickles something of the nature of lymph. Moreover, what shall I say respecting that oleaginous lymph which is found between the pia meninx and the tortuous and deep anfractuosities of the cerebrum! This is by no means supplied by the cortical glands of the cerebrum and cerebellum, for after you have wiped off the latter you will certainly not observe anything of the nature of humor flowing out therefrom. Nay, the reverse, since the entire inner surface of the pia meninx, after being further wiped, always moistens, and abounds with a whitish mucous springing from every direction, and this even though it be torn away from the dura mater and the cerebral cortex. That this same lymph abounds in oily particles needs no better proof than sight and touch. If you use your eyes, the pia mater will be discerned, in some cadavers, to be sprinkled over with innumerable round and whitish particles,—a fact to which my attention was called by an observation of that most diligent anatomist Ruysch to the effect that in various places the pia meninx is rich with fat." [*Opera. Romae,* 1741, pp. 116-118.] *So likewise the arterioles which creep between the two layers.* The arterial offshoots which wind in the duplicature are present in the greatest abundance. Now if the mater itself sustains so numerous a cohort of arterioles which at various points adhere to it and which pierce both itself and at the same time the arachnoid tunic, according to the observation of Ruysch,—moreover a certain fibrous offshoot connects the two, (n. 334),—and if secretion be granted to the arteries of the cerebrum as it is granted to those in the body, it necessarily follows that a perennial humor perpetually flows between the two membranes, that is, under the arachnoid. *When the cerebrum and cerebellum, and at the same time the medulla oblongata and medulla spinalis, swell up during their alternate animations, juice is expressed, and it is taken up by the spaces between the two layers; no otherwise than as is the case in the membranes of the body on every alternation of the diastole and systole.*

344. *As to the nature of that juice it is known from its source and from the tunic itself. The source, which is the pia mater and the smallest arterioles, can pour out no other dew than such as is of a better nature, that is, than purer blood together with suitable serum.* In the Transactions on the Blood and the Cortex,* it has been shown throughout that the red blood, as it passes into the smaller arteries, is divided into a purer blood which is white and which is styled by us the middle blood and middle animal essence; for the grosser serum is rejected in every direction, and the purer, together with a like blood, retained. A better humor of the same kind is also drawn off from the cerebrum. Moreover, in the Transaction on the Pia Mater, it comes to be demonstrated that this membrane is purely vascular, that is, is woven of the extreme capillaries of arterial vessels, but not of the genuine fibre of the cerebrum; for no fibre is reflected into this mater from the cerebrum. Now if it be vascular it must also necessarily distill a noble shower, and this under the arachnoid, that is, from its outer surface; while from the inner surface comes a subtle fatty humor with which that moisture is mingled. And, therefore, Ruysch rightly deems (n. 334) that it is not fat that is contained in those little cells. *The tunic itself, that is, the arachnoid, is a delicate tunic, than which a more delicate does not exist in the body,*—as Ruysch cautions us three times as against Bidloo, n. 334 above. *The contained juice and the containing tunicle most exactly correspond to each other. Thus the lymph must certainly be of the most chastened nature; that is to say, it must be a most highly rectified serum commingled with the purer blood,—such, in fact, as is found in this dupli-*

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*Economy of the Animal Kingdom, vols. i and ii.

cature. "Vessels of the utmost minuteness, (says Ruysch in the description of his table), are brought to view by the inflation, and they derive their origin not only from the aforesaid inflation but also from a watery moisture which lodges between the membrane in question and the pia mater" (n. 333), and, moreover, in hydrocephalic subjects,—descriptions of whose brains frequently occur in anatomical works,—in whose brains these spaces are everywhere filled.

CHAPTER III.

THAT THE LYMPH CONTAINED UNDER THE ARACHNOID TUNIC FLOWS DOWN BETWEEN THE MEDULLARY FIBRES OF THE CEREBRUM AND THE NERVE FIBRES OF THE BODY.

345. *In the Transaction on the Fibre it has been shown that between the medullary fibres of the cerebrum and the nerve fibres of the body are little interstices through which trickles a most highly rectified humor.* That there are little interstices between the fibres, n. 192; that a humor permeates those interstices, and what its nature, n. 194, 203, 209; and that this humor showers down from its very origin, that is, from the cortical substance,* n. 197, 218, 344. *For this end the arachnoid tunic takes up a most highly chastened lymph exhaled from the pia mater and secreted by the interfluent arterioles, and sends it down through those finer anfractuosities, sulci and furrows whereby the cortical cerebrum is discriminated and the pia mater divided.* For there are lesser and least anfractuosities, which we style furrows, obliquely and variously extended between the larger, especially at the bosses of the cerebrum; into all these the pia mater slightly bends down and insinuates itself, and through them all flow down arterioles. *When the mater is expanded during the intumescence of the cerebrum, it sends it away. This lymph is aptly derived to the spaces between the cortical glands, and thence to the spaces between the fibres; for when this juice falls down to those lesser interstices it can be carried nowhere else than*

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*In the Latin this sentence is printed in italics.

to the spaces between the fibres. Confer n. 197, 218. Especially must this be the case if purest stamens detached from the pia mater form the softest meninx of the cortical gland; and therefore, the humor can flow off into no other spaces than those which are intercepted by the cortical glands, n. 172. *For in the medullary substance of the cerebrum are smaller and larger plexuses of fibres through which this humor is continued all the way to the nerves,* 195, 229.

346. *Where many cortical glands flourish, and where they are most highly active above the rest,—as is the case in the sinciput or prow of the cerebrum,—there, not only is the pia mater more particularly and frequently furrowed, but it is traversed by more numerous arterioles and the arachnoid tunic is divided into more minute cells; to the end, namely, that it may administer fluids distinctly to each fibre and to each fascicle of fibres; and this in accordance with every need, as demanded by each fibre according to the degree of its activity.* That the cellular tissue of the arachnoid tunic is more abundant near the top of the cerebrum than elsewhere, is established by all our authors,—Ridley, n. 327; Winslow, n. 330, 331; Heister, n. 332, and Ruysch, n. 334.

347. *Likewise in the medulla spinalis to which it is closely bound on the anterior side, and loosely on the posterior; for from this medulla through a chink, a passage opens* (*together with a great abundance of arterioles*) *into the cortical substance, in order that thence it may provide for the several interstices between the fibres.* In these particulars also we have the consent of the authors cited. *So also elsewhere; whenever there are many cortical substances, and fibres springing from them, they demand a greater quantity of humor.*

348. *But where the origins of the fibres, that is to say, the cortical glands, which are directly covered by the pia mater, are conglomerated not so near the surface, there the arachnoid is not distinguished and connected up into so many cells; and hence it does not become so closely adherent to its accompanying meninx, but is stretched out and smoothed into a flatter membrane; as is the case in the region more remote from the top of the cerebrum, over the cerebellum, frequently in the* *medulla oblongata, and at the posterior side of the medulla spinalis.* Consult the authors quoted above.

349. *The arachnoid tunic, wherever it goes, is still attached to its pia meninx by means of septa, but here more strictly, there more loosely; in one place more densely, in another more sparsely; and also in divers ways. In such way, however, that from one cell there is a passage opening into another,—a passage which has continual respect to the origins of the fibres whose interstices it irrigates with the required humor.*

350. *These tunics dispense this fluid not arbitrarily but by law and command. For it is action in the extremes, that is, in the muscles of the body, that governs the quantity; that is to say, a greater action demands a greater quantity, and a lesser action a less. For the motor fibres of the body whereby action is determined correspond to the medullary fibres and to their cortical glands in the cerebrum which determine the action. Thus it is these glands that designate the amount of which they have need, and that agitate the meninx spread over them, and the arterioles, in such measure that these pour on the proportioned amount of humor.*

351. *Without a perennial spring and interfluent lymph of this nature fibres would easily grow together; and then the individual forces of the fibres and the individual forces of the muscles would coalesce into simultaneous forces and finally into general forces,—as is usually the case in subjects worn out by old age, and in other subjects, in whom motor fibres no longer carry out the will of their animus.* See above, n. 193, 225. *Hence this lymph is as it were a lubricant which anoints, smoothes, and lubricates the hinges. The contrary effect results when this inflowing humor is too serous or sluggish, as is the case in dropsical subjects, paralytics and epileptics.*

352. *When the animal draws its dying breath, and the brain makes its animations more deep, and rises and throbs to greater height, that is, spends all its powers and resources for the restoration of the organic and motor machine of the body; and when the arteries, soon to collapse, drive the full tide of their blood into the veins, and themselves secern nothing; then,* *whatsoever of humor lies under the arachnoid is expelled into the fibres. Thus the membrane is emptied out. This is the reason why, in the dead, it is rare that any quantity of this lymph comes to view.*

CHAPTER IV.

THAT THIS SAME LYMPH IS DERIVED TO THE SPACES BETWEEN THE LAYERS OF FASCICLES IN THE NERVES.

353. *Each fascicle of fibres, which, within the cranium and the vertebral sheath, is called the beginning of a nerve, is covered with a double or triple tunic. The inmost regards the fibre and the outmost the fascicles associated together in the nerves. These layers are held apart and prevented from coalescing by a juice of the utmost fluidity. This juice is none other than that which trickles between the fibres, or which, also for this use, is laid up under the arachnoid tunic.* That the tunic of the fascicles is double or triple, see above, n. 215, 216, 217. That ligaments run from the inmost tunic of the nerve into the outmost tunic of the fascicle, n. 221, 222. As to the use which the duplicatures of the membrane perform in the nerve, see 224, 227.

354. *The arachnoid tunic not only covers the cerebrum and cerebellum but it also accompanies the beginning of the nerves, both in the cranium and in the medulla of the spine, all the way to their exits; and thus it sprinkles the same noble juice between the layers as between the fibres.* That this tunic, induced over the beginnings of the nerves, follows them all the way to the foramina in the cranium and vertebras, confer Ridley, 329,—but, from their appearance when seen by the naked eye, Ridley calls those beginnings fibrils. Winslow, however, describes the matter more accurately, n. 331; and he is confirmed by Heister, n. 332, and others. *Thus it appears that the principal charge of the arachnoid tunic is over the nerves in the body.*

CHAPTER V.

THAT THE ARACHNOID TUNIC IS A PERPETUAL LYMPHATIC DUCT IN THE CEREBRUM, CEREBELLUM, MEDULLA OBLONGATA AND MEDULLA SPINALIS.

355. *Lymphatic vessels such as occur in the body have long been sought for in the brain, but hitherto they have not been found. For the universal arachnoid tunic or duplicature is one single vessel or one single lymphatic duct,—but one that is continuous and is projected into a plane, that is, is extended breadthwise at the same time as lengthwise.* Pacchioni, to say nothing of other anatomists, expended considerable* labor in detecting lymphatic vessels in the cerebrum; and he asserts that he has found a number of them in the pia meninx. But other keen sighted anatomists affirm that such vessels have been seen only in diseased brains. These vessels moreover openly communicate with the arachnoid tunic, of which they seem to be folds or corrugations. Nuck affirms that a lymphatic vessel was seen by him in the choroid plexus, but none as yet in the surface of the cerebrum [n. 335a]. But it ought to be plain from the use whether it is required that they exist in the brain in the same way as in the body.

356. *The lymphatic vessels of the body carry a lymph purged of every dreg; a like lymph is also carried by the arachnoid duct within its tunicle. For when their nature is explored both lymphs, subjected to heat, fly off into a subtle vapor, nor do they leave anything earthly and dead, as does common water. Thus they agree in nature.* The lymph of the cerebrum,—which is the same as this lymph contained under the arachnoid tunic,—and that of the lymphatic vessels has been tested by many and it has been found that both lymphs present the same nature and purity. From other tests it may also be concluded that the lymph, both of the brain and of the lymphatic vessels, is not purely elementary,

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*The Latin is *nullam operam,* which means "*no* labor." But the sense shows that our author has inadvertently omitted the word *non,* so that the phrase should read *nullam non operam,*—as translated in the text.

but is commingled with animal [substance], such as is suitable to the blood in order that it may be recompounded; wherefore all the lymph in the body is carried off into the veins.

357. *The lymphatic vessels of the body are visibly woven of a most delicate membrane, than which there is none more delicate. So likewise the arachnoid membrane, especially in the uppermost region of the cerebrum;* as is acknowledged by Ruysch, n. 334. The delicacy of these two membranes, of itself proves nothing except that the contained juice and the containing tunic mutually correspond to each other, n. 344.

358. *The lymphatic vessels of the body are not continuous ducts like the arteries and fibres, but are interrupted, and are of a vesicular and cellular structure, though pervious from cell to cell with an open passage,—which perhaps is demanded by the nature of the fluid; exactly as is the case in the arachnoid tunic, which is not continuous but is attached to the meninx by intermediate septa, and is discreted into numerous cells with a passage opening from cell to cell.*

359. *The lymphatic vessels in the body draw their juice from the last extremities of the arterioles; thus they draw a purer blood associated with a suitable serum. Such a juice is also drawn by the arachnoid duct,* see above n. 344.

360. *The lymphatic vessels convey almost all their juice, collected from every viscus, muscle, gland, into a single thoracic duct; but the arachnoid duct is, from the very first, a single duct diffused throughout the whole encephalon. For the viscera and muscles of the body do not cohere, nor do they concord in the forces and moments of their action; and, therefore, the lymph must be conducted into one stream. The case is different in the brains and their medullas.*

361. *The lymphatic vessels of the body unload their pure lymph* into the veins, and especially into the subclavian; to the end that their juice may return by a circle from blood to blood,*

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*The text has merely "suam puram,"—the addition of the word "lympham" being required to complete the phrase. Having in view Swedenborg's usual style, we suspect the true reading to be "suum succum," as in the preceding paragraphs.

and may enter the red blood which is resolved at every turn of the circulation. It is a little different in the case of the arachnoid duct which, in fact, unloads its juice not immediately, but mediately, after it has first passed through the structure of the nerves; see above n. 199, 200, 319. *Moreover the cerebrum pours a similar, fresher, and still more noble essence into its jugular veins and by these into the same subclavian vein, from the opposite side to that from which the lymphatics pour in theirs.* That the cerebrum transmits a copious animal juice from its anterior* and third ventricles, through the infundibulum, and by means of the pituitary gland, into the jugular vein, will be seen demonstrated in the Transactions on the Cerebrum.

362. *Such then is the agreement between the lymphatics of the body and the arachnoid of the brain. The lymph is of like nature and origin. The membrane itself is of like texture,—both tunics being, without doubt, cellular,—and of like fineness. Thus they mutually correspond to each other, and perhaps mutually respect each other, in the way, namely, that this lymph of the brain, after passing through the nerves, is poured into the arteries of the body; from the arteries it returns through the lymphatics into the veins; from the veins, by means of the heart, into the arteries, and that which returns to the carotids is again unloaded into the common lymphatic vessel of the brain, and so, passing through the nerves, it again returns into the lymphatic vessels of the body through a perennial circle,—except as concerns that part of it which is spent on the uses of the kingdom. Thus prudent care is taken that nothing of this noble offspring, the lymph, shall be lost until it has performed its use in the inmost penetralia of the body.*

363. *That this universal duplicature of the cerebrum is made up of an infinitude of lymphatic ducts coalescing into one, is, for one reason, because the origins of the nerves are scattered through the cerebrum and cerebellum and also through the medulla oblongata and medulla spinalis, and all*

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*The lateral ventricles.

these origins, and consequently the nerves, in whatsoever corner of the body they act, must be provided for from a general [centre]. And because there is a passing from one cell to another, there is a most perfect communion of this good or lymph, as there is also of the blood in the cerebral arteries, and of the juice in the arterial tunics, n. 179. *For whatever of fluid is found in one cell of the arachnoid, this same is communicated to all the cortical glands, the fibres, and the nerves in the body; so that there is not a fibre which cannot make demand on this public for what it needs, and as it were assert to itself as though its own, all that is in the common store. This is of the greatest importance to the nervous system and to the whole animal economy which depends on the state of that system.*

364. *For on this tunic's or arachnoid's integrity, continuity, connection with the pia meninx; and on the quantity, quality and dispensing of this lymph, depend the lot and condition of animal life. For from its defect the fibres grow together; from its affluence they are held apart; from its malignity they are puckered up and wounded, and, together with the appended motor fibres, are agitated into stormy motions; and so forth.*

365. *The meeting place, whither flows all this lymph contained under the arachnoid, is the lowest and posterior region of the medulla oblongata around the calamus scriptorius. Thither it flows down from both brains and is derived from every circuit of the medulla oblongata.* "A looser duplicature, (says Ridley), was found at the extremity of the calamus scriptorius," n. 329. *And from there it goes down through the great foramen of the occiput to the posterior part of the medulla spinalis.* In that region a passage opens also for the pituitary lymph contained between the dura and pia meninx; for there is an intervening space. But this is not the case in the anterior region, according to Vieussens' observation. *In that place also there is a reticular plexus, not unlike the choroid, which sprinkles on its fluid.* The reader will see this plexus and the signal use performed by the fourth ventricle and the calamus scriptorius, treated of in our Transactions on the Brain. *For the arachnoid tunic adheres to the anterior part of the spine more closely, and, therefore, the fluid is led around to this opposite side as to its meeting place. According as the affluent stream is greater, so the membrane is strengthened; and, therefore, in the medulla of the spine it is denser, somewhat reddish with bloodvessels, and constitutes its second true integument.* That the arachnoid tunic in the medulla of the spine is besprinkled with bloodvessels, is not denied by Ruysch, although he is sharply contending against Bidloo that in the cerebrum it is the most delicate of all membranes. The spinal nerves also demand a considerable quantity of this fluid, since they are the nerves that enter into the most active muscles of the body.

CHAPTER VI.

THAT THE ARACHNOID TUNIC PERFORMS MANY OTHER USES.

366. *The arachnoid tunic also restrains the grosser and pituituous humor, collected between the dura and pia mater, from flowing down to the spaces between the lesser folds and tortuous ridges of the cerebrum and infesting the fibres in their beginnings, that is to say, stopping up the little spaces between the cortical substances; for a sluggish and pituituous humor of this kind, if poured around the cortical glands, would easily stop their activities and agglutinate the junctures of the fibres.*

367. *From the arterioles under the pia meninx, there is also secerned an immense supply of serum; but it is fatty and sluggish because freighted with urino-saline and sulphureo-saline particles of the resolved blood. Unless on these particles were poured the more limpid and fluid liquor distilling from this duplicature, the fibres would be bathed about by too rough a moisture, whereby they likewise would be rendered unfit for action.*

368. *By means of this tunic also, a host of arterioles is maintained unseparated in their natural situation and stream; for arterioles creep in due manner in the duplicature of both* *these meninges and are attached to both by fibrous connections.* See Ruysch, n. 334. *For on their arterioles depend the cortical glands; on these the fibres; on these the nerves; and on the nerves the whole animal machine. Hence it is the arachnoid tunic, conjointly with the pia meninx, which constantly holds the arterioles and by consequence the several things dependent on them, in suitable situation, distance, connection, order, law, form, mutual respect, determination,—and this, howsoever the cerebrum is expanded or constricted, lifts itself up, is tumultuous, is jarred or struck.*

369. *The arachnoid tunic, with what power it can, also maintains the connections of the surface of the cerebrum divided into serpentine tracts and diversiform areas; for it overlays the several divisions, larger and smaller, that is, the sulci, while the pia meninx folds and insinuates itself into them. For when the arachnoid has been removed and the cerebrum thus laid bare, they all come to view.*

PART III.

DISEASES OF THE FIBRES.

DISEASES OF THE FIBRES.

CHAPTER I.

THAT ALL DISEASES IN THE ANIMAL BODY ARE DISEASES OF THE FIBRES.

370. *There are diseases of the solid parts, there are also diseases of the fluid. Solid parts are the bones, cartilages, tendons, cuticles, membranes; nay, even bloodvessels and also fibres, viewed as to their tunics. The fluid parts are humors of divers kinds, such as the gastric juices, the salivas, the pancreatic juices, biles, chyles, the lymph of the thoracic duct, milks, the genital fluid; in general the red blood with its serum, the purer blood or nervous juice, and the purest blood or first essence of the blood. But whether the part be solid or fluid or soft, it still pertains to the fibre; for there is nothing in the universal body save the simple fibre.* THE FIBRE, chapter xxiv [nos. 314-316]. *From this is derived the compound, or medullary and nerve fibre; and from this the bloodvessel, which is a fibre of the third order.* THE FIBRE, chapter xxii [nos. 298-303]. *And except fibres and vessels, there is nothing substantial that enters into, raises up and determines the form itself.* THE FIBRE, chapter xxiv [nos. 314-316]. *Moreover, a fibre is not called fibre, nor is it a fibre, without its fluid or blood; or the container and the content act as one cause. From these considerations it follows that diseases of the fibres in a broad sense embrace all diseases, in general and in particular; that is, the pathology both of the body and of the animus.*

CHAPTER II.

THAT DISEASES OF THE BODY, PASSIONS OF THE ANIMUS, AND CHANGES OF STATE OF THE MIND ARE AFFECTIONS OF FIBRES IN GENERAL.

371. *Ultimate fibres are the blood vessels; mediate fibres are the nervous and medullary fibres; first fibres are the simple, which are the beginnings of the rest. There is red blood in the ultimate fibres, or vessels; there is purer blood in the mediate fibres; and there is purest blood in the first or simple fibre. Therefore, there are diseases of the bloodvessels or of the red blood; there are diseases of the mediate fibres or of the purer blood; and there are diseases of the simple fibres or of the purest blood.*

372. *Diseases of the red blood are diseases proper, and indeed are diseases of the body. They spring for the most part from the red blood itself and its vitiation and malignity. From this do the other humors take their vitiation; and thence the glands, muscles, viscera, the vessels themselves and finally the nerves. Diseases of the body are of many genera and innumerable species; these are here to be treated of.*

The remedy for these diseases is obtained from drugs, and hence from the mineral, vegetable and animal kingdom; likewise from regulation of the food or from dieting; from motion and rest, sleep, the temperature of the air, tranquillity of the mind; and from such other means as are found to purify, emend and redintegrate the blood.*

373. *Diseases of the purer blood or nervous juice are not diseases of the body, but are properly of the mind,* and are called sicknesses, passions, and also affections of the mind.* For the nervous juice, that is to say, that juice which runs through the medullary and also through the nerve fibre, is the*

**Animus* the lower, external or animal mind. We have usually carried this word over into the English, but in the present chapter, whenever the word occurs in phrases of common usage it has seemed advisable to render it "mind"—distinguishing it from the rendering of *mens* (the rational mind) by an asterisk.

same as the animal spirit which rules, not only in the nerves of the body but also in the medullary substance of the cerebrum, cerebellum, medulla oblongata, and medulla spinalis, and which also passes through the middle of the cortical glands which, taken together, constitute the common sensory. Therefore from a vitiated state of the spirits arise sicknesses which affect immediately, not the body but the mind of the body; such, for instance, as anger, fury, jealousy, species of ludicrous haughtiness, melancholy, inconstancy of moods, impatience, foolishness, timidity, excessive ardor of the concupiscences and excessive slackness, weakness of the imagination, lack of memory and finally privation thereof,—and many other ills which are affections of the cerebrum and are attributed to the heart. Nevertheless they inflow into the body, just as the purer blood inflows into the red blood and the fibres into the bloodvessels, and thus cause diseases.*

The remedy for these is also obtained from drugs which purify and restore the blood; and, moreover, from the festive board and from agreeable and complaisant society; also from moral philosophy. But it should be carefully ascertained whether these sicknesses arise from depravity of the red blood, that is, from some disease of the body, or from causes of their own, or from a perverted state of the intellectual mind.*

374. *Diseases of the purest blood are not sicknesses of the animus, but are proper to the intellectual mind to which belong perceiving, thinking, judging, willing,—faculties which do not pertain to the animus but to a sphere which is above the animus in man; it is otherwise in brute animals. Such diseases are not, properly speaking, diseases,—which are of the body,—nor sicknesses and passions,—which are of the animus; but rather they are affections of the mind and perversions of its state. Such are various loves of self, vain ambitions, misanthropy, hatreds, excessive desires for depravity whence come malice and insanities whereof there are many species; imbecillity, and also excessive heat in thinking and*

**Ex convictu,* literally from eating together.

judging, and the phantasies arising therefrom; nay, also stupidity, and many other ills,—all of which spring from a preconception of false principles respecting the connection and order of causes and ends, arising from obsequiousness and complaisance toward the animus and its unbridled cupidities; and especially from the banishing of conscience. Hence come evils themselves, vices, transgressions, which lay waste and destroy their whole republic.

For the purest blood or first essence of the blood, which determines the simple fibre, is not the animal spirit but is the external form of the soul. From this essence and its fibre is raised up the cortical substance wherein our rational mind finds abode; for it is the substantial form thereof, or the first organic form of the soul,—a form, namely, that is aptly framed of simple fibres; and as many as there are of such substances so many little brains and internal sensories are there. Hence in accordance with the internal state of this substance, is changed also the state of our rational mind; and if this is perverted, then spring forth hallucinations and insanities.

The remedy for these is obtained from the same remedies as emend the animal spirit and the sicknesses of the animus; also that the mind suffer itself to be informed by masters who have saner judgment; thus from natural theology and also from revealed; especially that the mind curb and restrain its animus and the impetuosities thereof, and thus set itself free under its own law and liberty.

375. *But we must carefully discriminate and judge as to what diseases are of the body, what of the animus, and what of the mind; for it is often the case that the one so inflows into the other as to make it appear as though they were always coexistent.* DISEASES OF THE BODY *are all those diseases that arise from causes which act in the bloodvessels, that is, within the bloodvessels; and which act outside the nervous and medullary fibres, but yet upon them, consequently also outside the cortical glands, but yet upon them; also outside, and upon, the organic forms raised up by these fibres.*

Sicknesses of the animus *are all sicknesses that arise from causes which act in the nervous or medullary fibres, that is, within those fibres; and which act outside the simple fibres, but yet upon them, consequently also within the cortical glands but yet upon them.* For according to the description in Transaction II [n. 69 *seq.*], the cortical gland is a tiny ventricle (like a heart) or a follicle, which passes through the middle of the gland and is continued into a fibre, that is, into its canal. Around this follicle is the body of the gland woven of simple fibres; consequently, when the purer blood passes through this follicle it is said to act within the gland but yet upon it, that is, upon the simple fibres. *Also outside of and upon the organic forms raised up by the simple fibres.*

Perverse changes of the state of the intellectual mind[†] *arise from causes which act in the simple fibres and within the simple fibres; as also which act outside the substances or forms of the soul, but yet upon them, consequently, which act in the cortical glands which are the first organic or external forms of the soul*

376. *From the above, it is apparent that there are still higher diseases; for the soul is above our intellectual mind and the intellectual mind is the external form of its soul, which is the internal or inmost and supreme form of its system. But of the soul, neither diseases are predicable, nor sicknesses nor affections, but rather guilt, and consequently essential changes of state. But because the soul, properly so called, is above the simple fibre, therefore its guilt can be allotted no place among diseases of the fibres.*

CHAPTER III.

THE INFLUX AND CORRESPONDENCE OF THE SICKNESSES OF THE BODY, ANIMUS AND MIND.

377. *No one, I believe, calls into doubt the fact that our intellectual mind, namely, its thought, will, love and desires inflow into the animus and its imagination, whence are excited*

[†] In the Latin edition these words are printed in italics like the rest of the paragraph.

cupidities, and that these inflow into the sensations, expressions, actions and pleasures of the body; for he who reflects a little upon the things which exist in himself, realises that the universal corporeal system is so connected that what is superior and interior acts into that which is inferior and exterior, and also vice versa. *This fact is more than sufficiently proved by experience alone; for the mind frequently so operates into the body as to trouble and darken the blood; as, for instance, when the mind is desirous of some end and this escapes it, the animus becomes so angry, inflamed and furious, that the blood grows hot and the bile is expelled from the gall bladder, and fever seizes upon the viscera, nay, even upon the lower intestines so that they are twisted into a knot. Consequently there is a perpetual influx and a perpetual correspondence; nay, whenever they do not correspond, a combat is excited, whence arises disharmony which is the cause of many sicknesses and diseases. But to treat of this influx is the work of an entire volume.*

378. *All diseases of the body whatsoever, recognize some corresponding sickness in the animus, and, corresponding to this, an affection or change of state in the mind. But although they correspond, they are not therefore to be denominated in the same way; as neither are diseases themselves. They are called, diseases in the body; sicknesses and passions in the animus; changes or perverse states in the mind; guilt in the soul. The pain which is in the body is called anxiety in the animus, evil conscience in the mind, hell in the soul. Bilious fevers in the body are anger, fury, resentment in the animus, burning hatred in the mind. The one also excites the other. Paralysis in the body corresponds to foolishness in the animus, and to fluctuation of the will and lack of the power of determination in the mind. So also in the other diseases. But there is no way of setting forth the correspondences of all the diseases until the nature of each has been explored.* Respecting correspondences and their application the reader will see marvels in the Transaction on this subject.*

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*See above, n. 307, note. In the Latin this sentence is printed in italics.

379. *The correspondence of diseases is of like nature as the correspondence of grosser, purer and purest blood; or as the correspondence of bloodvessels, nerve fibres and simple fibres; of heart, brain and cortical substance.* THE FIBRE, chapter xxiii [nos. 306-308]. *For these are forms which mutually succeed each other and, like as they mutually correspond to each other, so also do they mutually inflow into each other, act and suffer. From this it is plainly apparent how many are the parts required for the science and art of medicine in order for its utmost perfection.*

CHAPTER IV.

THE GENERAL CAUSES OF DISEASES OF THE BODY.

380. *There are general causes both of diseases of the body and of sicknesses of the animus, and also of the essential changes of state of our rational mind; but here I shall treat only of the causes of diseases of the body.*

381. *All those agencies are causes of diseases of the body, which change a better state of the blood into a worse. When the blood is changed, then all the humors that come from the blood as from their storehouse and seminary, are also changed; and, with the blood and humors, the vessels and the several fabrications of vessels and fibres, and consequently also the members and viscera, and finally the whole corporeal system.*

381a. *The first, principal and most general cause of diseases of the body is its sustenance, that is to say, its nourishment from substances dry and liquid. Aliments are substances which refresh and renovate the blood and, at every turn of the circulation, restore it after its dissolution; and which especially subminister those elements that enter into the chyle and constitute the serum whereby the blood is redintegrated. On the quantity, quality and dispensing of the aliments depends the temperament of the blood. An excessive quantity, even of aliment of the better kind, that is to say, intemperance, is injurious. The quality of all foods and drinks is different; one is suitable, another unsuitable, according to the nature of each person's blood and body. The dispensing, a matter which is of the* *utmost importance, demands that a larger or smaller quantity of aliments of this quality or of that be furnished for the use of refreshing the blood. Therefore the most general cause of disease is a quantity of a quality of aliments badly dispensed. But the special causes of this condition are as many as are the species of aliments and the natures of the persons feeding upon them.*

382. *The nature of the effect produced by the aliments that are taken in is shown by the excretions of the bowels and also by those of the bladder, that is, by the urine; by the pulsations of the arteries, the respiration of the lungs, the changes of the animus, and discomforts that happen to the viscera. The specific and individual signs exceed all number.*

383. *A secondary and more remote cause of diseases of the body is that subtle nourishment, little obvious to the senses, which is drawn in from the circumfluent air, by the respiration of the lungs and by the cuticles, and is introduced immediately into the capillary veins. These aliments are both dry and liquid, and they find lodgment in the air.* For, diffused in the air, are nitres, urinous and sulphurous substances, dews, waters, essential juices whence come odors. What is effected by the presence of aerial nitre in the blood, and also by the presence of pestiferous vapors, is shown by experiments. Moreover, when the hands or face are wet, sometimes the water is absorbed even to dryness, and sometimes it is thrown out. Thus our corporeal system is like, as it were, to the system of the atmospheric world, which now impregnates itself with vapors and now clears itself from them by showers. *The pores themselves are opened and closed according to the needs of the red blood and according to the state of the purer blood. Of these aliments, the amount insinuated is so great that it sometimes exceeds the amount of the aliments taken in by the gullet; as is shown by the example of men who have sustained life for a long time without food and drink, and of brute animals which pass through a long period on these foods alone. On the quantity, quality and economic dispensing of this aliment, also depends the temperament of the blood. But* *neither the quantity, nor the quality, nor the dispensing of this nourishment depends on our own arbitrament; for it is remote from the senses and is governed for the most part by a certain intelligence* whose instinct and moving cause is hidden from us. But more prudent dispensation is made by this intelligence, than is made by us in respect to aliments obvious to the senses,—aliments which, of our will, we put into the mouth and stomach without discrimination.*

384. *The effect produced by these aliments is known from the pulse, the respiration, the affections of the cerebrum, the quantity and quality of the sweats,—for there are paths of excretion from the arteries just as there are of deglutition by the veins,—and at the same time also from the digestion, sleep, wakefulness, and other signs as yet unknown.*

385. *A third and still more remote cause of diseases of the body is that insensible perspiration, called the Sanctorian,*† *by means whereof the aliment is drawn, not as before from the air, but from the ether; nor is this aliment led immediately into the veins or red blood, but it is led through certain fibres towards the cortical brain.* Respecting these points compare THE FIBRE, chapter ix [n. 168 *seq.*], and Transaction IV ON THE ANIMAL SPIRIT‡ where the corporeal fibres are treated of. *And is thence insinuated into the purer blood for the integration of the animal spirits and thus is derived into the medullary fibres and by them mediately into the blood; for as the red blood, in order for its refreshing, enjoys its little mouths and organs, so also does the purer blood. This point is placed in sufficiently clear light by the experience of centuries, especially of our own. On the quantity, quality and economy of these elements, depend the nature and condition of the purer blood,*

**A quodam sciente*, literally "by one who knows."

†The Sanctorian perspiration so called from its discoverer, the Italian anatomist Sanctorius, is that insensible perspiration of most subtle humor which exhales from little vessels, the sweat glands under the epidermis, which are much finer than the miliary or sebaceous glands. They are called by Swedenborg "pores of the second kind." (A. K. 505.)

‡See n. 81, note, and n. 242, note.

that is, of our animal spirits; and because the latter flow into the red blood and constitute its principal essence, it must needs be, that if they be malignant they act as the roots of diseases of the body.

386. *One cause of diseases of the body which must also be referred to the class of general causes is the sickness of the animus which depends, as on an external cause, on the nutrition mentioned just above. Of this sickness there is also an internal cause, namely, the state of the mind itself,—a state which rouses and moves the animus also, as its servant, to the carrying out of what it wills and desires. But this is the supreme and most remote cause of diseases of the body; for it is quite evident in the clear light of experience that a disturbed mind disturbs the blood of the body, nay, frequently to such an extent that from any excessive desire for an end, together with the loss thereof when hope fails us, we are thrown headlong into passions of the animus, and from these into diseases of the body, nay, into death.*

387. *The four principal and general causes of diseases, recounted above, are the same causes as those by which we exist and subsist, that is, by which we live in the body; they are also the same as those from which we die; so that the causes of corporeal life are also the very causes of diseases and likewise of death. For we live on aliments drawn from the earth, and from air and from ether, but a quantity of a quality of these aliments badly dispensed, is the verimost cause of diseases, or of the fact that every day we draw nearer to death. Ignorance as to the quality of nourishing foods, as to our constitution and as to the art of dispensing, that is to say, as to how quantity and quality should be dispensed with a view to the constitution of the recipient body; and, moreover, the fact that such matters are left to our will and its desires,—these circumstances produce the effect that the same causes which are causes of life are causes of the destruction of life. So likewise the affections of our animus and mind; for as many as are the desires, and as many as are the cupidities, so many are the heats and excitements of life; but an immoderate* *excitation,—that is to say, an immoderate quantity,—and indeed of those desires which tend to depravities and are inimical to us,—that is to say, of a worse quality badly dispensed,—produces the like result, namely, that it is the cause of our destruction or death. Just as abuse or quantity injures, so does defect or too great paucity. That the causes of life are the causes of diseases and consequently the causes of death, is the very nature of nature; to wit, that in her several causes and her several subjects, opposites and contraries are present in potency, whence come acts; for every created essence is by nature subject to change, privation and destruction.*

388. *The* OUTMOST *of all the causes that produce diseases is that which acts outside the bloodvessels, but yet upon them, and consequently outside the organic forms raised up by the bloodvessels, but yet upon them; that is to say, which acts upon the outmost surface of the body. Of this nature are violent assaults, blows, wounds whence result copious emissions of blood, luxations, contortions,* or injuries inflicted on the members, organs, head, etc. Of these causes some are fortuitous, and some voluntary. They are* FORTUITOUS *when they come in some unforeseen or unexpected way, such as by the fall of a house, a ball thrown from a sling or gun, a tile falling on the head from the gutter of a roof, and like accidents. They are* VOLUNTARY *when one lays hands on himself, desires death and invites it; so also if he invites diseases. There are also causes* MEDIATE *between the fortuitous and the voluntary, as in the case of duels, battles, and perils by land and sea.*

389. *Just as there are outmost causes so also are there* INMOST *causes which are the first causes of all, or the causes of causes and the verimost essential. These, since they are not voluntary or of the mind but are above voluntary causes*

**Contorsiones.* Blancart's *Lexicon Medicum* (ed. 1777) defines this word as meaning an incomplete separation of any member of the body from its connections so that it leaves its natural position. Thus it includes all kinds of sprains, strains, displacements and muscular contortions.

which are of the mind, are called CONTINGENT CAUSES; *for they come from some other source, nor do we know whence; and therefore we attribute them to fortune, fate or providence; such, for instance, as our coming into one or other of the dangers of life and the diseases arising therefrom; coming, namely, by chance, into those causes which are outmost and have just been recounted, or upon noxious aliments, or into places where are poisonous and deadly vapors, into emotions of the animus and desires and immoderate heats of the mind, and into innumerable like things, that is to say, into all the causes of diseases. But since there is no such thing as pure chance or fortune or luck; and since there is a series and connection of contingent causes from firsts; and since first causes in the animal body arise from the soul; hence so also do the contingent causes of disease. These therefore necessarily spring from the soul as from their fount, and from its change of state; that is to say,—according to the nature of the soul, or according to the nature of its reception of the influx of life from the supreme spiritual form, such is the contingency which inflows into the series of our life.* But these points are treated of in the Transaction on Providence.*

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*A chapter on "Divine Providence, Predestination, Fate, and Fortune" was to have been included in Transaction vi, On the Soul, or Rational Psychology (3 *Doc.* 831), and in fact these subjects are dealt with in the posthumous work on the Soul, in the chapter "On Divine Providence" (*Soul,* 549-561). But the author seems to have also written a separate little work on this subject; for at the end of the chapter just referred to he says: "But Providence, Fate, Fortune, Predestination, and Human Prudence have already been treated of; these you may consult and subjoin" (*Soul,* 561). This treatise is evidently one of those little "Transactions" which the author designed to publish "not less than five or six times a year" as contributions to his great work. In an edition of ŒCONOMIA REGNI ANIMALIS in 1742 four such treatises were announced as "to be published." They are all parts of Transactions v and vi as outlined by the author, and the last of them is entitled "On Divine Providence, Predestination, Fate, Fortune and Human Prudence." (1 *Doc.* 585). This is undoubtedly the work referred to in THE SOUL, n. 561, and also in our text as the "Transaction on Providence." The work itself has never been found.

390. *Such then is the series of the* ESSENTIAL CAUSES *of life, diseases and death, from the inmost or contingent cause through intermediate causes to the outmost. In addition, there are mediate causes of diseases, ultimate causes, innate causes, and superadded causes. Essential causes concern the origin of diseases, mediate causes the progression, and ultimate causes the effect; innate causes are hereditary, superadded causes are acquired.*

391. MEDIATE CAUSES *are those which impede the causes of life in their* PROGRESSION *from first origin to effect; for they are causes which entirely inhibit the progression of aliments, both terrestrial and aerial, and also etherial; likewise, which inhibit the emotions of the animus and mind,—emotions which are the heats of life whence come diseases. Progression is promoted by sleep, wakefulness, motion, rest, social intercourse, occupations, and many other conditions. If these are not suffered to progress in their natural order, diseases arise, the causes whereof are said to be* MEDIATE *between those that furnish the origin and those that produce the effect. For diseases flow from excessive sleep, excessive wakefulness, excessive motion, excessive rest; or from the privation of these and also from the privation of occupations by which we are roused up.*

392. ULTIMATE CAUSES *are those which restrain or entirely stop the* EFFECT. *Effects are the discharging of the bowels and bladder, sweat, the Sanctorian perspiration, the exercise of venery, the hemorrhoidal, menstrual and salivary flux, and many others. If these are impeded diseases ensue. For all causes have a certain series from the first point to the last; and so also the causes of life, diseases and death. If origin is denied, progression and effect also come to nothing; if effect, the course and progression from origin to the effect provided by nature is also denied. Now because the effect is the ultimate in the series of causes, therefore these causes are called ultimate.*

393. INNATE CAUSES *are hereditary, that is, are derived from parents.* SUPERADDED CAUSES *are those which come from the previous acts of life and put on a nature as though they were innate; they are also called acquired causes, and some of* *them become hereditary. But neither of these causes can properly be said to be the causes of disease, since they are only dispositions for receiving diseases of one kind or species or another. The subjects are of universal variety. The blood of one is never entirely like that of another, as neither are the animus and mind. Therefore we are more or less prone or slow to the taking of diseases. One thing innate with all of us, and which we derive from our parents as a universal characteristic, is our decline and ultimate death. Therefore, with advancing age, we come into sicknesses or infirmities, the complement of which, or the last line drawn under the sum of the sicknesses, is the death of the body.*

394. *We have thus distributed the causes of diseases into their classes; for without a distinct knowledge of causes there is no distinct, still less any certain science and art of healing. Each disease can, as I believe, be reduced to one of the classes defined above. But recapitulation will perhaps be of service. Of diseases there are* PRINCIPAL *or* ESSENTIAL *causes; these are many in number, one following the other. The* FIRST *or* INMOST *is called the contingent cause. After this comes the* SECOND, *which results from the state of the mind and animus; the* THIRD, *which results from the use of etherial aliments; the* FOURTH, *from the use of aerial aliments; the* FIFTH, *from the use of terrestrial aliments;* OUTMOST *causes, which act upon the forms of the body extrinsically. Since there are essential causes it follows that there are also* ACCIDENTAL CAUSES, *to wit, all those causes which arise from the essential; as, for instance, those which arise from vitiation of the humors born of the blood. Philosophically speaking, all causes of diseases are accidental except that first cause which is called the inmost. But these subtleties we pass over. The causes just enumerated are those which give* RISE *to diseases; after these come* MEDIATE CAUSES, *which inhibit the* PROGRESSION *of the natural causes of life; and* ULTIMATE CAUSES *which inhibit their* EFFECT. *But* INNATE *and* SUPERADDED CAUSES *are not active causes but passive; thus, properly speaking, they are states recipient of causes; for wherever there is an active there must be a passive.*

CHAPTER V.

PARALYSIS AND PARESIS.

395. *Paralysis arises when the red blood is intercepted or impeded as it flows into the smallest vessels of the motor fibres of the muscle; but if the animal spirit is intercepted or impeded as it flows into the motor fibres of the muscle, apoplexy results; thus paralysis differs from apoplexy. The animal spirit and the blood are the two principles which actuate the muscle; for the former excites it to action, while the latter restores it, whence come the muscle's alternate motions. Therefore when there is a deficiency of one or the other the reciprocation perishes; for the spirit is the agent while the blood is the reagent, and the agent knows no terminus except from its reagent by which it is determined into prescribed motions and thus into alternations of motions.* There are some, nay, many, who confound the cause of paralysis with that of apoplexy; for to both alike they ascribe a defect of the nervous fluid and an influx of the blood. But that these diseases differ, and how much they differ, is known to everyone. But a distinct knowledge of the causes of both diseases depends upon a distinct knowledge of the muscle and its motor fibres, and of the forces acting into them; also on a distinct knowledge of the blood and its vessels; and especially on a distinct knowledge of the nerves and of the interstices which pass through the porous structure of the nerve. A muscle cannot succumb to disease unless it is paralytic or apoplectic, that is, unless there is a deficiency of blood or of animal spirit; for it is well known that if the artery or nerve of a muscle is torn, the muscle loses its faculty of action. Therefore privation of the blood cannot be the same cause as privation of the spirits; the blood is in the vessels, but the spirit is in the fibres of the nerves.

396. *If the prevention of the flow of red blood into the capillary vessels of the motor fibres is the proximate cause of paralysis, the question arises, In how many ways is this* *blood intercepted? The* FIRST *way is, if the arteries flowing into a muscle or part of a muscle are stopped up, compressed, torn, or become tendinous,—that is to say, the larger or common arteries. The* SECOND *is, if the capillaceous vessels themselves which encircle the motor fibre become exsanguinous and coalesce into threads of a tendinous nature. The* THIRD *is, if the arteries secrete and unload an abundance of serous humor, and the veins and other ducts fabricated by nature fail to take it up and carry it off. By reason of this the muscle and its membranes and ligaments are inundated and relaxed; thus not only is the muscle rendered impotent of action, but, in addition, the more minute vessels do not admit the blood into their cavities.* FOURTH. *A similar effect results if there is an abundant afflux of humor from the nerves,—namely, through the interstices of the fascicles of fibres which are somewhat open.* Respecting these interstices see THE FIBRE, chapter X [nos. 188-207].

397. As regards the FIRST: *The arteries are* STOPPED UP *from causes in the blood; as, if the blood be clotted, pituitous, cold, sluggish, filled with bile, concreted into fibres, destitute of spirit, or itself spurious. They are* COMPRESSED *by ligatures, a reclining posture, neighboring abscesses, fistulas, ulcers, contortions* of the members. They are* TORN *by erosions, ulcers, aneurisms, applied force. They become* TENDINOUS *from privation of the influx of spirits into the fibres of the muscular tunic, or of blood into the other tunics; from the stopping up of the glands situated in their tunics; and from inaction.*

398. With regard to the SECOND: *These smaller arterioles* COALESCE *by reason of too great inactivity, of fat, and of the same causes that produce tendinification in the larger arteries; age also causes them to diminish, to coalesce, and to be obliterated and end as lines of a tendinous nature.*

399. As concerns the THIRD: *A flow of ichor or serum arises from the closing of the paths of evacuation, such as those between the motor fibres, through the surrounding mem-*

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*See n. 388, note.

brane and the skin, nay, through the bladder and bowels; and from the compression of the absorbent veins. Thus if the veins are compressed, stopped up or become tendinous, a similar effect results as in the case of the arteries. Thus when a muscle with its membranes and ligaments has become relaxed and flaccid it no longer possesses in itself the power of action. Moreover, the humor has the effect of impeding the influx of blood into the vessels of the motor fibres. The same is the case if a pure serum somewhat sluggish in its nature inflows into these same vessels; for such serum resists the active nerve fibre; the case is different with the blood.

400. As to the FOURTH: *If an opportunity of discharge is denied to the humor that flows out from the interstices between the fascicles of a nerve, the motor fibres, or the muscle with its membranes, are in like manner relaxed and infested with waste matter. For when a nerve is unfolded, all the humor that is carried down through the interstices between its fascicles escapes, and, having performed its function, is rejected; but if it is denied an exit, it is accumulated in the muscle. This humor is brought to the nerve in the region of the cortical substances; for when the arteries are inflamed it is collected in the sulci or anfractuous folds between the layers and reticular plexuses of the medullary substance, and under the dura mater where the fascicles of fibres unite into a nerve. In this way do they secrete their lymph in the cerebrum, cerebellum, medulla oblongata and medulla spinalis, in the nerve itself from the arteries which pass over it, and between the fascicles.*

401. *From this it follows that a paralyzed muscle is soft, relaxed, as it were loosened from connection with the neighboring parts, hence deprived of reactive powers and thus incapable of elevation by any power of the will, devoid of sensation except one that is mute and is stimulated by pricking, and as it were dead flesh, unless the fibre be living. It can be revived if the disease does not have its seat in the primary viscera of life, such as the heart, lungs, stomach; as a rule, also, it has its seat in the lower intestines, the abdomen, bladder, thorax, shoulders, arms, loins, feet, neck, and face. When it is of a lighter character it is called* PARESIS.

402. *Paralysis is of a more universal nature when the affected veins are nearer the heart, or when the nerves from which this malady springs are nearer the brain or further distant from the muscles. The paralysis of one muscle is felt by the neighboring muscles according to their connection with it, —especially by an antagonistic muscle; in their own way also they suffer from it. From various indications, those skilled in matters anatomical know wherein the seat of the disease lies; from this and also from causes, judgment may be made as to whether it is curable, whether or not it is fatal, and what measures must be used.*

403. *After a somewhat severe paralysis has persisted for a long time, many of the arterioles remain collapsed, the ligaments of the muscles too greatly extended, flaccid, and partly ruptured, and the membrane somewhat loosened from its flesh; so also the fascicles and their tunicles and ligaments; sometimes the larger vessels are injured. Hence come unordered motions, at times convulsions, debility, tremor, shaking, lack of obedience to the several decisions of the brain, and many other symptoms.*

CHAPTER VI.

APOPLEXY, HEMIPLEXY, PARAPOPLEXY, PARAPLEXY.*

404. *In order that we may know all the species of apoplexy and their causes it is necessary that we know from the most searching exploration what office is performed by the cerebrum, what, properly, by the cerebellum, what by the medulla oblongata, and what by the medulla spinalis; what connection they hold with each other; how one or the other flows conjointly and also separately into the muscles, and consequently into the viscera of the body. From the anatomy of the cerebrum it is evident, that the* CEREBRUM, *or its cortical substance,*

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*HEMIPLEXY is the paralysis or palsy of one side of the body; PARAPOPLEXY, paralysis of the lower half of the trunk; PARAPLEXY, paralysis of the lower limbs.

which, properly speaking, takes the name Cerebrum, is the COMMON SENSORY; *for the five organs refer their external sensations to the cortex of the cerebrum as to their common and sole internal sensory. The* CORTICAL CEREBRUM *is also the common* VOLUNTARY MOTORY; *for whatever is to be done by the mediation of the nerves and muscles must first be determined in the will by the cerebrum.* THEREFORE THE CEREBRUM IS THE COMMON SENSORY AND THE COMMON VOLUNTARY MOTORY, AND, IN FACT, THE PRIMARY AND PRINCIPAL. *But the* CEREBELLUM *is not a sensory, or is only a most general and obscure one to which no particular idea, such as comes to our consciousness, is represented except by the effect. Hence the cerebellum is called the common spontaneous, natural and involuntary motory whence come those actions which are called instincts. Thus the* CEREBELLUM IS THE PRIMARY AND PRINCIPAL COMMON SPONTANEOUS MOTORY; *and the difference between it and the cerebrum, is of the same nature as the difference between the voluntary and the spontaneous natural; or between that of which we are made conscious and that of whose origin, progress and effect we are wholly ignorant. The* MEDULLA OBLONGATA, *on the other hand, partakes both of the fibres of the cerebrum and of those of the cerebellum; for fibres from both these organs are brought down into it, and of these, as also of its own proper fibres, it is made up. This medulla is, as it were, a medium uniting the cerebrum and cerebellum and a medium simultaneously transferring the sensations of the five external organs to the cerebrum, and the hidden operation of the viscera to the cerebellum, and also the decisions and commands of both to the muscles. It may be called* A COMMON SENSORY AND MOTORY BOTH OF THE CEREBRUM AND OF THE CEREBELLUM, BUT A SECONDARY ONE, AND A SUPERIOR INSTRUMENTAL. *So likewise the* MEDULLA SPINALIS, *which is structured of fibres of the cerebrum and cerebellum and also of its own, deserves to be called a* COMMON SENSORY AND MOTORY, BUT A SECONDARY ONE, AND AN INFERIOR INSTRUMENTAL, *in that it is nearest to the body.*

405. *Moreover, we ought also to know what connection the cerebrum, cerebellum, medullà oblongata and medulla spinalis* *maintain with each other. The connection can be explored from the connection of the membranes, sinuses, arteries, and fibres. From this it is evident that these four viscera of the encephalon, or superior kingdom, that is to say, the cerebrum, cerebellum, medulla oblongata, and medulla spinalis, are so mutually inter-connected that the cerebrum can act into the cerebellum and, conjointly with this, into the medulla oblongata and medulla spinalis; but then every action is called voluntary,—action which is done in the daytime or in wakefulness. Likewise, that the cerebellum can act into the cerebrum and, conjointly with this, into the medulla oblongata and medulla spinalis,— but every action thence resulting is called spontaneous-natural, such as takes place at night or in sleep. Further, that the cerebrum and the cerebellum equally vindicate to themselves the right of acting into the underlying medulla oblongata, that is, into the annular protuberance and the olivary and pyramidal, and consequently into the nerves springing from these protuberances; but that the cerebellum asserts to itself a fuller right of acting into the fourth ventricle, the region thereof, and the subjacent medulla spinalis,— which latter can be excited generally by the cerebellum, but not so by the cerebrum except in particular, and by means of the cerebellum. But these points will come up for demonstration in the Transactions on the Cerebrum and its Membranes.* Meanwhile, without a previous knowledge of the whole brain we can never deeply explore the causes of apoplexy, epilepsy, catalepsy, hydrocephalus, coma, and many other diseases. With these premises let us now enquire as to apoplexy and its species.*

APOPLEXY.

408. APOPLEXY *is the impotency of the common sensory and the voluntary motory, that is, of the cerebrum and, in fact, of its cortical and cineritious substance, to sensate and act, that is, to receive by means of the fibres the images of the organs of the five external senses, and to excite from previous will the muscles to action,—the life and motion of the cere-*

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*The Latin is *membris* (members), which we have corrected to *membranis.*

bellum nevertheless remaining, and consequently the life and motion of part of the medulla oblongata and likewise of the medulla spinalis. Thus apoplectics, deprived of the use of the better corporeal life, live only in the blood and body, except as regards an obscure life which emanates from the cerebellum and the underlying medulla spinalis and which is like to our life during sleep and in the mother's womb, nor is it much unlike death; for they no longer retain anything of themselves as their proprial own,—which is thought or inmost sensation, and will, which is the beginning of action. But since the cerebellum does not succumb, there still remains the pulsation of the heart and arteries, which is stronger than ordinary; and likewise the respiration of the lungs, loud and stertorous as in deep sleep. For the cerebellum with the medulla spinalis claim for themselves the empire of the heart and also of the lungs, since the fibres of the pericardium and of the cardiac muscle itself, and also the fibres of the pulmonary plexuses and likewise of the intercostal muscles, belong equally to the cerebellum and the medulla spinalis; for they belong to the intercostal nerve and to the eighth pair of the head, and also to the dorsal nerves.

407. *All causes which render the cortex of the cerebrum impotent of action, that is, of animation or respiration, produce principally apoplexy of the whole body, that is to say, of the sensory and motory organs, inasmuch as these are voluntary. The faculty of animation is the very life of the cerebrum; for by means of animation the cerebrum receives sensations and carries out motions; and indeed by means of the animal spirits which course through the middle of the cortical glands and through the medullary and nerve fibres. For when the cerebrum quiesces, the animal spirit, which is the purer blood, is no better able to run through the fibres than the blood is able to run through the arteries when the heart quiesces.*

408. *These causes are many. The primary cause is obstruction in the trunk of the internal carotid before it is divided into branches,—and this whether the obstruction happen outside the cranium, or in the passage through the bony foramen,* or anterior or posterior to the swelling formed by the carotid in*

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*The carotid canal of the temporal bone.

the receptacula cavernosa.[*] *If the carotid is obstructed in its further course, that is, in its branches, there arises, not general apoplexy but only apoplexy of one half of the cerebrum, or of a single part in one hemisphere. Respecting these species of apoplexy see below.*

409. *But the causes of the obstruction are many; to wit: an abundance of glutinous, viscid, gross, cold, inert blood which stagnates at the entrance; the connate or acquired presence, in these arteries, of tumors, scirrhus growths,*[†] *abscesses, fatty tumors,*[‡] *and many other obstructions which stop up the artery from within or compress it from without. The carotid artery is proper to the cerebrum, while the vertebral artery is proper to the cerebellum and likewise to the medulla oblongata, and in part, to the medulla spinalis. When the vertebral arteries remain entire, the cerebellum and the said medullas enjoy their ministering blood and carry on their animations even when the cerebrum is quiescent or as it were absent. But of these arteries, only a very little part ministers to the cerebrum, in order that it may derive some feeble life, but not sensitive and voluntary; for the vertebral artery so communicates with the carotid artery that the one inflows into a branch of the other and lives from the blood of the other.*

410. *Although this is the primary cause of apoplexy still there are other causes which affect the cortical cerebrum in like manner, and they are several in number; but they all look to that primary cause as the cause proper. For the cerebrum, by the force of its animation, attracts blood from the cavity of the carotid,*[§] *but the heart does not intrude it upon the cerebrum. Hence, whatever inhibits animations in the cerebrum, this also inhibits the drawing up of blood from the carotid artery and from the vertebral.*

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[*] The lateral grooves of the sella turcica.

[†] *Scirrhi,—A scirrhus,* from a Greek word meaning to harden, is a hard tumor which in the beginning is without pain but is apt to degenerate into cancer.

[‡] *Steatomata,* sing. *steatoma,* from a Greek word meaning tallow, fat.

[§] *i. e.,* the swelling referred to in n. 408. For anatomical authority as to this swelling see *2 E. A. K.* 18, 63.

411. *Such as viscid serosity, sluggish phlegm, and also extravasated blood which, collected within the pia mater and between the larger windings and lesser folds, and poured around the cortical glands, deprives them of all power of acting, of unfolding and constricting, that is, of animating. Such a condition arises from an immoderate secretion of malignant blood, from inflammation, and from impeded discharge; and these again from their causes which are still more remote and which yet are the sole causes to be remedied. The paths of discharge are many in number, as for instance, through the veins into the larger sinuses, through the cribriform plate into the cavities of the nostrils, and into the nerves as respects their fascicles; and these paths are closed more strictly and the phlegm of the cerebrum increases more largely when, in addition, the paths for the general excretions are not open, as [for the feces and urine] through the bowels and bladder, for the saliva through the cavity of the mouth, for the menstrual flow. When these paths are closed the cerebral cortex is inundated and also the cerebral medulla; and then, by reason of these two inundations, if the flow is tenacious and sluggish, the animatory force is stopped and thus the afflux of arterial blood; and consequently the sensory and motory force of the cerebrum; whence arises apoplexy.*

412. *Moreover, a viscous and copious flow between the dura and pia mater produces a similar effect. For the intercepted humor so compresses the arachnoid tunic and its subjacent pia meninx together with the arteries and veins lying between them, that the cortical substance can by no means be elevated, that is, can by no means engage in its alternations of animation.*

413. *A similar effect also results to the cortical substances of the cerebrum if the three cerebral ventricles, to wit, the two larger or anterior and the one intermediate which is called the third, are filled with so great an abundance of serum that the cerebrum is unable to determine or pour out the forces of its animation towards interiors. When the cerebrum is expanding and constricting it unfolds itself either* *outwards or inwards, that is, it tumesces or detumesces,—for there is room in both directions; for which end also are the ventricles and the space between the meninges. If there is no opportunity of tumescing or unfolding outwards, and if at the same time there is no opportunity of detumescing or folding inwards, the whole faculty of animation, that is, of sensation and voluntary action is entirely taken away from the cerebrum.*

414. *It is also a cause of apoplexy if the dura mater so thicken and flow with humor and become flaccid as to lose all its faculty of elasticity and reaction; or if this mater become indurated; and also if, being loosened from its connections with the cranium, its whole weight rest on the pia meninx and thus on the cortical cerebrum,—of which effects there are many causes. For the dura mater is like a spring or cord which reacts to the extent that the cerebrum acts. When the cortical cerebrum swells out in tumescence it will not again subside, if there be nothing present of a reactive nature, but remains in a state of inaction, and consequently in the privation of sensation and voluntary action. Thus it neither takes up the arterial blood from the carotids nor drives the uptaken blood into its own veins and sinuses. Neither do the sinuses themselves receive the blood; for they belong to the dura mater and are contained in its duplicature; nor are they actuated into alternations except by the motion of the cerebrum.*

415. *Meanwhile, the province of the cerebrum, although coterminus with the province of the cerebellum is so separated therefrom by septa formed from the dura mater and attached to the cranium, that the cerebrum performs its own offices in a distinct manner, and in a distinct manner the cerebellum; nor do they concur except in guarding the safety of the whole corporeal system. The cerebrum enjoys its own arteries, that is, the internal carotids, its own ventricles which are three in number, its own medulla, its own cortex, its own pia and dura mater, and its own sinus which is the longitudinal; the cerebellum also enjoys its own arteries, that is, the vertebral, its own medulla, its own cortex, its own pia and dura mater, its own ventricle which is hollowed out in the stem of the*

medulla oblongata, and also its own sinuses. Thus the action of the cerebrum may be stopped while the action of the cerebellum still goes on. And therefore apoplexy is an affection of the cerebrum; as soon as it becomes of the cerebellum also, it is at once deadly or death. Thus a malignant and hostile humor collected between the meninges and windings of the cerebrum and in its cortex, medulla and ventricles, does not invade the cerebellum; nor does it break out in the direction of the medulla spinalis unless the bars have been broken down; and so neither can it stop above or around the cerebellum since the path of exit opens through the foramen magnum of the occiput into the vertebral sheath at its posterior portion.

HEMIPLEXY.

416. HEMIPLEXY *or* HEMIPLEGIA *is a similar privation of animation, consequently of sensation and voluntary determination, of one half of the cerebrum, or of one of its hemispheres. The motion of the cerebrum should be conceived of according to the partitions of its cortical substances as being both general and special and also particular, consequently as being variously subdivided. For the cerebrum is partitioned into its hemispheres, these into their lobes, these into their serpentine tracts, these into their beds, these into their clusters, and these into their spherules which are again partitioned into lesser spherules and least. Hence also it is gifted with the faculty and capability of expansion in general, in special and in particular; for the whole can be unfolded, or a single lobe or a portion of the cortical substance. Wherefore, if one half or one hemisphere, or if one lobe, should become torpid from some grave obstruction, the other hemisphere or the other lobe might be actuated into alternate motions; and if this can be so actuated then also can one or other of the serpentine tumuli.*

417. *Thus if the carotid artery in the larger branch which leads to one hemisphere be obstructed with an abundance of glutinous, viscid, gross, cold, inert blood; or be stopped up by fatty tumors, polypi or excrescences; or be compressed from without; or if viscosity beset the cortical gland round about;*

or the pituitous serum around the fibres or collections of fibres in the medullary substance grow sluggish in the windings, conglutinate the folds, stop up one of the lateral ventricles, be collected between the meninges on one side of the longitudinal sinus; or if the dura mater, being too flaccid, should be remitted, or, being indurated should grow rigid,—then action is destroyed in the one hemisphere, whence arises hemiplegia.

PARAPOPLEXY.

418. PARAPOPLEXY, *on the other hand, arises when one or other of the divisions of the cortical substances is infested with these same ills. But in parapoplexy a still greater number of causes may concur; that is to say, besides the fluid glue collected in some place under the dura mater, the adherence of the latter to the cranium or its loosening therefrom, and the cohesion of one of the windings or sulci, there is, in addition, the possibility that by means of a like viscid humor the beginnings of the nerves may cohere together in their exit from the cranium and, after their exit, in the body, that is to say, between the fascicles. Hence arise tumors, sinuses and hollows, even in the ganglia and also in the muscles, namely, in their fibrous offshoots. A similar effect results from the compression, ligation, lesion, erosion, or amputation of the nerves.*

PARAPLEXY.

419. PARAPLEXY *or* PARAPLEGIA *derives its originating cause, not from the cerebrum, but from the medulla spinalis. For the whole body below the neck, or all the muscles whatsoever that are approached by the spinal nerves, are seized with apoplexy while the senses of the head remain entire, and also the free power of acting into their muscles. This disease arises from similar causes in the medulla spinalis as those mentioned above as existing in the cerebrum, with the difference that results from the difference between the fabric of the medulla and that of the cerebrum.*

420. *Meanwhile, since the connection between the medulla*

*spinalis and the cerebellum in man is such that the one can hardly be moved without the other; and since the spinal nerves from the dorsal region flow into the muscles that serve the respiration, and the intercostal nerve into the heart, vena cava and aorta,—which nerve is indeed sent off by the cerebellum but passes through the spine,—hence it cannot but come to pass that this species of apoplexy, if it degenerate into apoplexy soon becomes mortal; but meanwhile the heart and likewise also the lungs live for a short time by means of the eighth nerve of the head.**

CHAPTER VII.

SLEEP, CARUS, LETHARGY, CATAPHORA, COMA FEBRILE, COMA VIGIL.

421. *Sleep occurs when the cerebrum relapses into its natural state, such as it had maintained in the mother's womb, and rests from the emotions and affections of its animus; then, together with the cerebrum, collapse also its windings and sulci, and the spaces between the cortical spherules and medullary fibres. This is indicated by the tranquillity and innocence apparent in the face, and at the same time by the respiration of the lungs as being more regular, slow and deep, and not subject to the arbitrament of the will. Meanwhile, when the cerebrum quiesces the cerebellum moves and animates. Thus at night or in sleep the cerebrum relinquishes the reins and delivers them up to the cerebellum; and the latter, left to its own law, by means of its fibres and those of the medulla spinalis then actuates the pulmonary machine, and also the cardiac, into their alternate reciprocations; at the same time it actuates the muscles of the body, and when it flows into all these there results a complete equilibrium of the whole.* From the cause of sleep and wakefulness and from other connected phenomena, we learn by diligent anatomical study: that the cerebrum, by means of the medulla oblongata and medulla spinalis flows into all those muscles that are moved voluntarily; likewise also the cerebellum by means of its fibres; so that the fibres of the cerebrum, cerebellum and medulla spinalis proceed conjointly in one nerve, and prudently unite in the muscles themselves; but that the cerebellum acts into still other muscles, and indeed in such way that while it actuates one muscle it at the same time actuates another, even when the two are antagonistic; and because in this way one muscle cannot be excited against another, as is usually done by the cerebrum, there arises an equilibration of all the muscles. *Hence comes alternate rest and unrest, that is to say, the cerebrum sleeps while the cerebellum is awake and* vice versa. *It would be certain death if both should sleep, and uncertain life if both should rule equally at the same time.*

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*The par vagum.

422. *In sleep, whatever voluntarily excites the muscles and disposes the organs of the senses so that they distinctly receive and carry down the modes whereby they are affected, lies flat and prone. Thus sleep is the temporary death of voluntary actions and of sensations. Consequently sleep is an affection of the cerebrum alone, which is both the common sensory and the common voluntary motory. But as to how the cerebrum is affected, this must be learned from the minute anatomy of all its parts, as of its substances, meninges, members, and of its connection with the cerebellum and with the subjacent medullas. The cerebrum is divided into hemispheres, [these] into convolutions like those of the intestines, and these into their convolutions most exactly discriminated by furrows and ridges. One fold, commissure and duplicature passes subdivided into another, scarcely other than as the great artery ramified into its lesser and least arteries. When all the partitions and ramifications of the cortical cerebrum yawn open distinct and rightly discriminated, that is to say, when the cortical cerebrum is so expanded and erect that there is an open passage from one furrow or fold into another, then the state is that of its wakefulness, attention and intentness. But when the cortical cerebrum is collapsed, that is to say, when one congeries of the cortical substance is incumbent upon another and the discriminations are almost ob-*

literated, then the cerebrum is in the state of its sleep, obscurity, insensibility, and indeterminability, that is, in impotence to will action and to sensate. For TO WILL *is to determine into act what has been concluded, there being added the desire for some end in the mind, or the cupidity for something present in the animus. But* SENSATION *in the cerebrum is the perception of images and modes which flow into the mind from below, from the external senses and from the memory. The cerebrum cannot determine into act that which it wills and strives after, unless it perceives what is to be striven after; for according to the nature of the perception of sensations such also is the nature of the will of action, and vice versa. For* PERCEPTION, THOUGHT, JUDGMENT, CONCLUSION, WILL, *and* DETERMINATION INTO ACT *are in one series, first successive and then simultaneous. If the first in the series is intercepted, the last also perishes, for this depends on the first through the mediates. So also if the last perishes, progression from the first is at once stopped, and thus the existence of the first in act.*

423. *Therefore if we now demonstrate that the state of the cerebrum in sleep is such that it cannot perceive, or that it cannot determine into act the desires of its will, it amounts to the same thing. That the cerebrum may be able to determine into act what it wills or desires, it is necessary that it be in a condition to separately move its individual cortical substances or their congeries which are distinct or separate from each other and which excite corresponding muscles in the body. If the cerebrum collapses and by the collapse obliterates its distinctions, then, assuredly, the cerebrum cannot rule over any muscle in particular but only over all in general. Impotence to effect single individual motions or determinations is what is called sleep. In order therefore that the cerebrum may go to sleep it is necessary that it close up and collapse and thus, as regards its single individuals, extinguish its power to act.*

424. *But it is in every way important to know the nature of the state of the erect or expanded cerebrum, that is, the state of wakefulness. Every emotion or affection of the animus* *elevates, erects, unfolds, that is, wakens up, the cerebrum. Gladness, exhilaration, nay, ambition and any like heat, expands the cerebrum in every direction to the utmost corners of its cranium; for the fact that the cerebrum then tumesces is apparent from indications and from the very sensation. On the other hand, sadness, humility, the privation of hope desired, constricts the cerebrum not unlike as anxiety constricts the breast and pain the nerves. Anger and fury and like insanities pour out the cerebrum in divers forms and confuse it with a copious unchosen and malignant blood. It is affected in other ways by other emotions of the animus such as revenge, envy, fear, foolishness, love,—of all which we shall speak in their own places. That the general states of the cerebrum are so numerous, we see exhibited to the life in each person's countenance which is an index of the mind* (animus)*; but especially do we see it from the state of the respiration of the lungs which is wholly synchronous or coincident with the animation of the cerebrum. For the respiration of the lungs is sometimes constricted, sometimes exalted, sometimes variously confined or expanded, to wit, is strong, weak, rapid, slow, tacit, or gentle, in every way like as the cerebrum carries on its animations; in like manner the lungs apply and accommodate themselves to all the nods of the will of the cerebrum, or to its several animations, for the moving of the muscles or the production of actions. These are the general states of the cerebrum from which it rests, or from which it relaxes into its natural state when it begins to fall asleep.*

425. *The cerebrum relapses into this its state when, after the obliteration of its distinctions, the cortical substances close up or collapse; for thus perishes the distinct and diverse elevation or animation of the individual congeries of that substance, and in place thereof succeeds a general animation, or an animation of all the parts of the whole cerebrum,—an animation that is undiscriminated, one, or simultaneous.*

426. *As is the animation of the cerebrum such is its life. Individual animation, or animation of the single individual parts under the general, gives a distinct life, that is to say, a life potent for sensating, willing and determining the several* *things into act; for, as was said above, each single cortical protuberance corresponds to its own muscle in the body, which muscle the cerebrum excites by the individual elevation or animation of its cortical substance. General animation on the other hand gives a general, undivided and obscure life like that of the sleeping cerebrum and also like that of the wakeful cerebellum. Therefore whatever deprives the cerebrum of this power of animation, also deprives the cerebrum of the faculty of sensation and volition.*

427. *In the state of sleep, moreover, the red blood is restrained from approaching too near to the individual cortical substances, and is detained at a distance from them according to the degree of the slumber; for it is animation that draws the blood from the arteries and invites it towards the cortex; and therefore as is the animation such is the afflux, distribution and circulation of the blood in the cerebrum. Thus in sleep the blood brushes the outmost surface of the pia meninx, nor does it penetrate into the interiors of the cerebrum except by the more open paths, through which also pass the trunks; for it cannot penetrate towards the substance of the cortex through the winding folds and commissures, since these are constricted and collapsed.*

428. *From these considerations it is apparent what are the causes of sleep; every cause, namely, that inhibits and extinguishes the individual animations of the cerebrum and that restrains the blood from the cortex; for the cerebrum then collapses of itself and begins to fall asleep. The causes of sleep therefore are silence, ease, profound peace of mind, restfulness of the animus, lassitude, Venus, a soothing influence* (spiritus), *pleasant harmony; somewhat sluggish blood, a defect or large emission of blood, external compression of the cortical cerebrum, internal obstruction; these latter however are the causes of morbid sleep.*

429. *But among the primary causes of natural sleep must be placed the very necessity of the kingdom, that is to say, the necessity of restoring during the night what has collapsed, that is, has been destroyed or disturbed, in the daytime. For what the will destroys, this nature repairs; or, what wakeful-*

ness disturbs, this sleep recomposes; or, what the cerebrum confounds, this the cerebellum renders distinct, and what the cerebrum constricts, this the cerebellum relaxes; and also vice versa. *Thus unless the one acts and the other suffers alternately, that is, without sleep, the animal machine would not long cohere. Necessity itself notes, admonishes and as it were solicits, that the cerebrum, distracted and oppressed with weariness, should relax, and that the cerebellum, having taken its rest, should now rise unwearied and exert itself. And when the circulation of spirits, blood and humors, the economy and the universal state of the corporeal life, and especially of the cerebrum, has been restored, then the cerebellum abdicates its empire and restores it to the cerebrum, or, the cerebrum, become awake, spontaneously resumes it. From this it follows that among the causes of sleep is also anything that strongly excites the cerebellum.* That the cerebellum when left to its own law of action, that is, when the cerebrum is quiescent, animates more constantly, evenly, strongly and gently, in the degree that it animates more deeply, is a matter which we shall learn from the anatomy of the brain.*

430. *From the above considerations it is apparent: Why infants sleep more than adults, and the aged with greater difficulty. Why from too much sleep comes somnolence, dullness, stupor, weakness of memory, obesity, inaptitude for motion; that is to say, a more difficult erection of the cerebrum and unfolding of its convolutions. Why, when we are roused, we stretch the limbs, unfold the muscles, desire to sleep. Why the grosser kinds of nutriment have a soporific effect. Why, when we are heavy with sleep, the muscles gradually waver, first the eyelids and eyes, then the face and neck, then the arms and finally the feet; for the operation begins in the vertex of the cerebrum and descends by degrees.*

431. *But to resume. Each cortical gland, which is a little internal sensory, a little cerebrum in least type, and a symbol of our rational mind, sometimes continues, unchanged in sleep, in its own general state, which is a particular state relatively to the general state of all the glands, or of the whole*

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*In the Latin this is printed in italics.

cerebrum; for the state of the single individuals or parts, and the permanence thereof does not impede a change of the general state of the compound, as is well known in physics. Confer Transaction I, n. 287. *Just as all affections of the animus change the general state of the cerebrum and induce upon it a form suitable and accommodated to their own modes of action, or to their own nature, so all the desires of the mind, which have regard to some end, are so many causes that, in like manner, change the state of each cortical substance of the cerebrum and induce upon each in particular a suitable form. If these states continue or are changed in sleep the result is the excitation of dreams, visions, phantasms, divers appearances,—all which are so many representative images in the mind from the soul according to the state of the cortical substances and according to the ratio of influx into the general state of the cerebrum where are matters of the memory and images.*

432. *Reducing now the scattered causes of sleep, both natural and unnatural, to a unit, they are: I. Those that take away the individual animations of the cortical substances of the cerebrum and reduce them to one general indiscriminate animation. II. Those that detain and restrain the arterial blood from the cortex of the cerebrum. III. And, more particularly, those that fatigue the cerebrum and render it inert for action, while making the cerebellum active and alive. IV. The effect is, that the cortical cerebrum which is the common sensory and voluntary motory. begins to collapse and, by mutual application, to cohere as though not divided and distinct; consequently that the corresponding muscles in the body are not excited by any particular and individual force but all are excited simultaneously by a certain general force.*

CARUS.

433. CARUS *is an unnatural sleep of the deepest kind; those seized with it are as though living dead men, and even when roused up, after opening their eyes they at once sink back.*

434. *From the symptomatic signs it is apparent that the cause of this morbid sleep is the too dry, heated, and conse-*

quently hard nature of the red blood so that the globules or clots stick indissoluble in the smallest vessels. When the vessels are thus obstructed the cerebral cortical substance which is the common sensory and motory is deprived of its spirits and of the faculty of individual action. Therefore this heaviness of sleep is for the most part accompanied with fever.

435. *Add to this, that from blood thus dry, hot, feverish, and inept of solution, scarcely any humor is secreted except what is useless, accompanied with the smallest amount of spirit,—a humor whereby are stopped up the interstices between the cortical glands, between the fibres in the cerebral medulla and between the fascicles in the nerves, and whereon no arachnoid fluid is sprinkled. Hence comes sluggishness and torpidity extending from principles even to the universal nervous system. This therefore is a secondary cause of carus which yet acknowledges its first cause as lying in the nature of the blood.*

436. *From this it is clear that carus is not a species of apoplexy; for there is no compression of the cerebrum, either external or internal; that is to say, no clogging or inundation from a superfluity of pituitary humor in the convolutions, the medullary substance, the ventricles, or between the meninges. Neither is there any flaccidity or excessive rigidity of the dura mater. Hence there is no taking away of the common animation in the cerebrum,—as is noted from the respiration of the lungs. In apoplexy the respiration is exceedingly heavy (with the wings of the nostrils compressed) and struggling; thus it belongs to the cerebellum alone without the aid of the cerebrum in general. It is otherwise in carus where the respiration of the lungs goes on in a natural way and where the cerebrum itself is found to be uninjured.*

LETHARGY.

437. LETHARGY or LETHARGIA, *called by others* VETERNUS,* *is a species of unnatural sleep of a lighter character than carus. Those oppressed with this disease can be roused by*

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*A Latin word meaning "old age," and hence "lethargy" or "somnolence" as belonging to old age.

divers means, especially by such as excite and stimulate the animus and external senses, and thus restore the blood to its health.

438. *From indications it is noted that the cause of this disease is an abundance of serum in the blood, consequently a cold and sluggish nature of the blood and thus its not being easily introducible into the tiny arterioles of the cerebrum; for this is prevented by the copious serosity which must first be expelled. Hence the cause of this disease is obstruction from causes of cold, that is to say, from causes contrary to those obtaining in carus. For the cortical substance requires an abundance of resolved blood, since from this, its glands elicit their spirits which they transmit into the fibres and also, in part, between the fibres. Still there remains a general animation, to wit, of the lower part of the cerebrum, the corpora striata, medulla oblongata and medulla spinalis. This is known from the state of the respiration of the lungs; for the easier the respiration the more friendly is the concordance therewith of the general animation of the cerebrum.*

439. *A secondary cause of lethargy flows from a serum, also unvivified by spirits, secreted between the windings and folds and at the same time between the arachnoid tunic and the pia meninx. When the lesser folds and the little cortical spaces are anointed by this serum, they hardly suffer themselves to be elevated, but become torpid as from a certain cold. Thus neither is lethargy a species of apoplexy, but it approaches rather to the nature of hydrocephalus.*

CATAPHORA AND COMA.

440. CATAPHORA *and* COMA, *in Swedish* dvala, *is called also* COMA VIGIL *and* COMA SOMNOLENTUM *when the patient is neither asleep nor awake. Sometimes the patients lift up their eyes, sleepily answer what is said to them, and then sink back into their rest. There is dull thought without any desire or any emotion of the animus.*

441. *When such coma is a disease it is a species of carus; for it arises from a thickened blood which is denied passage through the smallest arterioles, though passage through the* *larger ones still remains. It arises also from a viscous excretion of the blood,—an excretion sparsely irrigated by the lymph of the arachnoid. Besmeared with this excretion, the folds between the cortical congeries stick, so that they can hardly be elevated except by reason of a cause powerfully stimulating the senses the animus and the mind, or by reason of some other cause which dilutes the blood and breaks up the slight glutinosity.*

442. *If it arises from heat or fever of the blood it is called* COMA FEBRILE; *or it also heralds fever; and is a species of carus. But if it arises from cold of the blood it is a species of lethargy.*

443. *There is also a non-morbid coma vigil, as when, after waking in the early morning, we are still as it were asleep as to the external senses and our mind reflects upon the quiet rest of its members and the delights of sleep. Such a state sometimes appears to be quite delightful; but we become fully roused up as soon as some emotion invades the animus or some delight the mind. For the smaller complicatures of the cerebrum, collapsed in sleep, are not yet well separated but lie joined together, though readily separable. And if we may be allowed to speak from interior anatomy the vertex of the cerebrum, which is the first to collapse and the first to be erected, seems to be raised from sleep while its inferior lobes stretched out over the cerebellum still lie as it were in slumber. On this account the respiration of the lungs is then natural and not yet mingled with the voluntary.*

444. *From these considerations, the cause of somnolence, from overly protracted or long continued sleep becomes evident; likewise the cause of the dullness arising therefrom. For the highly delicate commissures of the cortical clusters coalesce more strictly, and in the time of sleep are so conglutinated with a fatty juice, that they hardly suffer themselves to be separated from each other; and the tiny arterioles leading through these commissures into the cortex, and which have been compressed, hardly suffer themselves to be expanded. Thus with the distinction of the cortical substances, which are so many little sensories, perishes also the distinction of the internal corporeal life itself.*

WAKEFULNESS.

445. WAKEFULNESS *or lack of sleep is for the most part a concomitant and herald of fever; it is therefore called* FEBRILE WAKEFULNESS. *By reason of much wakefulness moreover, the circulations of the spirits, blood and other humors through their fibres, vessels and ducts, in their glands, muscles and viscera, both of the head and of the body, are continually interrupted, and some even cease; nor do they carry on their natural courses. Hence comes cacochymia,** *heat and hardness of the blood and thus many threatening ills.*

446. *The causes of unnatural wakefulness are the opposite of the causes of carus and lethargy, being, to wit, those that inhibit the cerebrum from weighing on itself and collapsing. Such causes are all burning affections of the animus, that is to say, all those sicknesses that maintain the cerebrum in an expanded, light and subdivided condition; for instance, as is obvious to everyone, gladness, anger, anxiety, care. The same effect is also produced by desires of the mind if they are conjoined with cupidities of the animus; add to this, unduly fluid blood which flies to become present at the least nods of its mind; and therefore also plethora; moreover, excessive fullness of the bloodvessels and also of the windings and little folds; evacuation from which, is denied in the cerebrum as a result of the denial of evacuation in the body, for instance, through the pores of the cuticle for the sweat and effluvia, also through the bladder, bowels, etc.*

447. *Cases of* WAKEFULNESS *and* INSOMNIA *frequently occur in fevers, because in fevers some clotting of a crude and parched blood sticks in the arterioles. In fever, moreover, heat, and also acridity, angularity and inequality in the red blood and in the purer blood, and also in the serum and lymphs, both in the vessels and fibres and also outside the vessels and fibres, perpetually stimulate, rub, inflame and excite the ani-*

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*Cacochymy or *cacochymia*, from two Greek words signifying "evil" or "depraved," and "liquid" or "humor," is, in general, a depravation of the humors of the body. It is defined by Blancart as "An abundance of vitious humors in the blood, namely, a degeneration of the blood, serum or lymph."

mus of the cerebrum; thus there is no peace and rest in the internal sensorium. For these conditions medicine is prepared from such things as mend the blood; also from NARCOTICS, *from* PAREGORICS *which are mild* SOPORIFICS, *from anodynes, etc.**

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*In illustration of the doctrine laid down by Swedenborg in the above chapter as to the nature of sleep, the following case will be of iterest; it was originally given by Dr. Pierquin, who included it in a paper published in the *Journal des Progrès.* The case was translated and published in the *London Lancet* (vol. II, 1829-30) from which it was reprinted in the *Intellectual Repository* (volume IX, 1848, p. 303) immediately following a translation of *The Fibre,* nos. 421-432. We quote from the *Intellectual Repository:*

"Rose ——, aged 26 years, of a lymphatic temperament, feeble constitution, small stature, with blue eyes and light hair, was a servant in Romans in the Department of Dióme in France, and was admitted an in-patient of the General Hospital at Montpelier in 1821, suffering from caries of the cranium with ulceration of the membrane which lines the inside of the skull, called the dura mater, allowing the brain to protrude through the opening like a fungus.

"During quiet sleep the swelling of the brain subsided so much that the organ semed to repose itself, at which time the pulpy swelling of the cerebrum withdrew entirely from the lips of the wound. During dreaming the cerebral swelling protruded. After she woke the protrusion regained its usual size. Often at the dressing hour the patient was not yet awake and it became necessary to arouse her from ordinary, long and sound sleep. The difficulty attending the passage from this cerebral inertia to activity was marked by such a state of orgasm that it became necessary at each dressing to take off a considerable portion of the pulp of the brain; an operation always unattended with pain, and unperceived by the patient who seemed to suffer no inconvenience from it. The patient was often subjected to the following experiment:—Whilst placed on her seat during the dressing we entered into conversation on some topic that might fix her attention. The moment she became engaged, the oscillatory movements of the brain became at once more rapid and stronger; pressure was applied upon the brain as strongly as possible, and in an instant the patient lost the use of all her senses, could no longer form an idea, ceased to speak, terminating the conversation in the middle of a word which she finished when we removed the compression and she then completed the phrase. These experiments were not only unattended with the slightest pain, but were unknown to the patient who never perceived the interruption

CHAPTER VIII.

CATALEPSY.

448. CATALEPSY, CATOCHE or CATOCHUS* *is a disease, in which, wonderful to relate, the person seized, becoming suddenly immovable like an image, remains rigid as a rock in the state which he had when he fell. On this account some of the ancients styled it* CONGELATION. *The patient remains in the same condition, not only in external state as to limbs*† *and muscles, but also as to internal state, namely, as to animus and mind, being held fixed in the ideas which he had conceived before the disease; and he is the less turned aside by any object, in that he is dead to the external senses. There remains however a weak pulse and a slight respiration of the lungs.*

449. *Everyone acknowledges that the proximate cause of such disease is the sudden quiescence of the common sensory and the voluntary motory; and at the same time that it is a disease of the cerebrum; for who doubts but that the cerebrum is that common sensory and motory? But if one enquires further he will confess that it is the cortical and cineritious substance of the cerebrum that becomes thus rigidly quiescent; for this substance is the beginning of the fibres and the end of the arteries, and to it, through the fibres, flow sensations, and from it the determinations of the will into act. Consequently it must be this substance that becomes quiescent in this disease; and if, when it is quiescent, there exists such immobility and insensibility, it follows that otherwise it is not quiescent, but that it moves, namely, in alternations, like the systole and diastole of the heart or like the breathing*

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to her intellectual existence, which was occasioned at pleasure.

"The number of pulsations in the evening were 120 in a minute, during sleep 98 or 100; in the dreaming state the number varied according to the agreeable or disagreeable nature of the dreams."

**Catalepsy*, from a Greek root "to be seized," and *Catochus* (French *Catoche*), from a root meaning "to be held fast," are two names for the same disease.

†Torus, means literally "a swelling, protuberance," or "the fleshy or muscular part." In other places, it refers to the "beds" or "tori" of the cortical glands.

lungs. This its motion is called animation. Hence on the animation of the cerebrum depends the faculty of sensating in the organs and of acting in the muscles. From this it is clear that the causes of catalepsy, apoplexy, carus, epilepsy and all other diseases that invade and affect the cerebrum can never be understood, still less be explained, unless we know the nature of the cerebrum; whence comes its life, that is to say, from animation, or, from the alternate expansion and constriction of its cortical substance; and that this substance, taken concretely, is the common and voluntary sensory and motory of the body.

450. *In this way we easily arrive at the cause of catalepsy,* that is, at the cause of the immobility of the cortical cerebrum, namely, that it lies in the denial to the blood of reflux from the arteries into the veins and into the sinuses; for thus animation, that is, the alternate expansion and constriction of the cortical substance, suddenly stops, and, by consequence, the circulation of the spirits from the cortex into the fibres and through the fibres.*

451. *Reflux is denied to the arterial blood if the longitudinal sinus is suddenly obstructed; as for instance, in the place where it is joined by anastomosis to the lateral sinuses, when the passage into one only of these is open, or when the passage into one is narrower than that into the other. Thus made turgid, the sinus spews back the approaching blood of the cerebrum. In order that nature may meet these conditions, she has added in many subjects a smaller sinus, also called the longitudinal, underneath the larger; and moreover, in some, she has constructed a communicating sinus between the two lateral.*

452. *Moreover, the superior longitudinal sinus is wont to collapse, and in this way also to refuse the blood of the cerebrum, if by chance the ligating cords of its walls, called the cords of Willis, by reason of too great tension are deprived of their power of reaction. Hence it comes about that in the*

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*In the Latin text the word is *Epilepsy,* but this is clearly an error. See ch. ix, below, particularly n. 458.

bodies of subjects who have died of catalepsy the arteries and veins appear turgid with a packing of thick cruor.

453. *The effect of this at once redounds on the cerebrum, namely, on its dura mater which is also distended and inflamed by the cruor; in like manner on the pia mater; on the whole cortex, and also on the medulla which goes off from the cortex; on the corpora striata, on the thalami of the optic nerves, and on the medulla oblongata. Only a slight amount of humor is carried off through the fourth sinus or torcular Herophili, that humor, namely, which the cerebellum introduces into the common viscera,—for the cerebellum still vibrates, though slightly, like the pulse of the heart and the respiration of the lungs.*

454. *If an obstruction of the longitudinal sinus, or also of the fourth sinus,—for, in cataleptic subjects this also may occur,—be the cause why cruor sticks in the vessels of the cerebrum from which it cannot get back through the arteries, the question arises, What is the cause of the obstruction? We answer, Every cause that renders the blood dry, thickens it, coagulates, defiles with heterogenous matter, fills with ramenta and fibres. Such causes are melancholy, excessive sadness, burning fever in plethoric subjects, quartan fever, retention of the accustomed evacuations, such as the menstrua and hemorrhoids; for of the blood that is drawn into the cerebrum, the better part is bestowed on the cortex and fibres, and the grosser, cruder and blacker is rejected into the sinuses,—which blood, at the threshold where it is poured into the jugular veins, is again vivified with spirit; also sudden terror which contracts the cerebrum and the cortical glands and banishes all the blood into the sinuses, which are venous receptacles, and from which it can effect no exit, since the other sinuses are also turgid with a like abundance, and the heart, timid and palpitant, is not able to admit and draw off the quantity that flows to it. Furthermore, inflammatory rigidity of the dura mater may also be the cause of the sinuses not intromitting the blood of the cerebrum; for the sinuses are situated in the duplicature of the dura mater, nor can they be expanded or constricted except by mediation of the mater; and with the sinuses remaining*

immobile the veins and arteries become turgid, and impotency of acting suddenly occupies the cortex; hence catalepsy. From this it is clear that this disease is for the most part deadly, or that it is followed by atrophy, dementia, epilepsy, convulsion.

455. *But it is a matter of import that we reduce the causes into order. The verimost cause is, that the cortex of the cerebrum is unable to expand and constrict and thus to transmit its animal spirit into the fibres and through the fibres into the sensory and motory organs of the body, or into the muscles. On this account the several parts remain in the same state as that in which is the cortical cerebrum both in general and in its parts. The cause of the cortex being unable to expand and constrict is blood sticking immovable in the arteries and veins and in the innumerable receptacles situated within the medulla; and that the blood sticks thus immovable is due to the sinuses of the dura mater not receiving it; the cause of this is obstruction or excessive relaxation of the sinus; the cause of this again is dryness and crudity of the blood and inflammation of the dura mater; but the cause of this is intemperance of life, while the cause of this is unrestrained lust of the animus, and finally, the cause of this is too great indulgence of the mind towards its animus, and the condescension of the soul.*

456. *A kind of natural catalepsy, quite familiar to many persons, is frequently noticed wherein, as in a mirror, we can behold the nature of morbid catalepsy. For there are those who, intent on some profound meditation, suddenly halt their steps, stand transfixed and motionless in the same state of body, countenance and senses, and, thus distracted, see scarcely anything except through a shade, nor hear anything except a kind of murmur; for some time also they hold the very breath of the lungs and when they breathe they carry on the alternations tacitly and slightly. Meanwhile the mind is intently fixed on a single object of the thoughts, nor is it drawn away by any motion of the body, or by any image of the sight or alien idea of the memory,—just as in the case of preternatural catalepsy. [In both cases] there is a like effect, nor is the cause* *unlike; for the cortex of the cerebrum, to which the underlying cerebellum is now obedient, is in deep rest and holds the blood at a distance from its little sinuosities and beds, nor, except sparingly, does it send it off into the sinus of the falx, which latter also is only slightly elevated and compressed. From these considerations it is apparent that profound meditation untempered by any variety may also be a cause of cataleptic disease, a fact moreover which is mentioned by many medical men as a matter of observation.*

CHAPTER IX.

EPILEPSY.

457. *The epileptic is suddenly prostrated, with loss of the senses, both external and internal, and interruption of the respiration; the body is tossed about with violent motions, and the ground is beaten with violent blows. Thus muscle rises against muscle, and the patient rages with paroxysms; so that there is a kind of combat of the life present with death, like the combat of death with life usual in the last agony.*

458. *That the cause of so dire a disease lies in the cerebrum is a fact which, I suppose, no one calls into doubt; for the source whence springs the life of sensations and the life of actions, is also the source of the death of the same; and it is the cerebrum alone that holds sway over the sensory organs and the motory organs. Therefore, from the effects is recognized what is the state of the efficient cause. From this it follows that epilepsy is a furious tossing and convulsion of the cerebrum, or an inordinate fluctuation, elevation and constriction of its cortical substances, whose every idea cannot be represented by reason of the repugnances of the motions in the body. Oh, to how many changes is not the human cerebrum subject! and into what dangers does not that voluntary and intellectual precipitate us, which is properly our own and belongs to the cerebrum alone! Therefore, whatever stirs the cerebrum into convulsive motions of this kind, and exasperates it beyond the mode of its accustomed vibration and the symphony of its parts, that same is the cause of this disease.*

459. *The proximate causes are:* [1] *Contusions of the cranium or fractures of the spine, exfoliations or excrescences of the whole* [*cranium*] *which with their sharp points prick and pluck the cerebrum.* [2] *Partial rigidity and a varying inflammation, or also ulceration, of the dura mater; also the tearing away of this mater from its connections with the cranium, especially in the region of the bones surrounding the bregma* and of the coronal suture.* [3] *A collection of corrupt matter, pus, acrid and fetid ichor, sticking somewhere between the meninges,—but especially under the pia meninx and between the divisions of the cortex, that is, in the smaller windings and sulci,—and the consequent hollowed-out pits and worked-in recesses, wherein a malignant humor either breaks in violently, or else dripping in little by little stagnates and putresces, and thus distends those openings so frequently that it cannot be wormed out except with the convulsion of the whole cerebrum.* [4] *Likewise similar collections, pittings and abscesses in the medullary substance of the cerebrum,—in its superior, middle or inferior region, around or within the ventricles,—or in the medulla oblongata and its beginnings and crura;*† *moreover little pools and asylums of the blood are frequent everywhere in the medullary portion, which, when beset with a sluggish and corrupt humor, deeply include the very root of the evil; hence come dilatations, displacements and distortions of the parts, erosions, ulcers. These causes, however, are the external causes belonging to the cerebrum, for they lie outside the cortex, being either above it in the integuments, or below it in the fibrous structure.* [5] *But the internal causes can be said to belong to the cortex itself, which, if it becomes schirrous, inflamed, indurated, putrescent, eroded or extinct, is then rendered impotent to break up or move forward the lymphs that are insinuated in the little folds; hence*

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*The bregma is a point on the top of the skull which marks the anterior end of the longitudinal suture where it meets the transverse or coronal suture; in infants it is the site of the anterior fontanelle.

†The thalami of the optic nerve and the corpora striata; see n. 104 and note.

receptacles are fabricated for epileptic matter which by the delay resulting from stagnation will degenerate into purulent filth.

460. *The causes that make the cerebrum to be thus ulcerated, pitted, corroded, or that bring these evils in and ingenerate them, are innumerable.* CONTINGENT CAUSES *are fractures, contusions, luxations or perforations of the cranium.* NATURAL *or* HEREDITARY CAUSES *are unusual interstices and cavities in either substance of the cerebrum; the constriction or narrowing of the ways leading to these interstices; the undue proportion of the cranium to the mass of the cerebrum itself; an ill distribution of the arteries; a radical vitiation of the blood.* ACCESSORY CAUSES *are malignant fevers, both hot and cold; undue temperature of the blood and its serum; excessive excretions; concretions, and innumerable other circumstances.* VOLUNTARY CAUSES *are discordant emotions, furies and tempests of the animus arising from insanity of the mind or from intemperance in the pleasures of the body. But the causes from which the above-mentioned evils exist are the same as those from which they subsist and by which they are excited.*

461. *The causes that rouse into effect this evil ingenerated in the cerebrum, (for the disease once inrooted breaks out at intervals), are, as was said, similar to those that produced it, such as:* IN THE BODY, *acrimony of the food eaten, corrosions and irritations of the viscera; especially of the stomach and intestines, such as are induced by worms; latent ulcers, imposthumes, abscesses, great and periodical pains; retention of the urine, lochia, menstrua, hemorrhoids; pestiferous exhalations and fumes infesting the blood and nervous juice; also the roots of several diseases, etc.* IN THE CEREBRUM *they are sicknesses of the animus, which are so many motions, disturbances, expansions, constrictions, contorsions of the whole cerebrum, and sudden alterations of its animations. In this way the offscourings hidden away in their hiding places, and the concealed seeds of the evil, are called out, whence arises collision, extrusion, intorsion; and thus the fibres and cortical glands, which are the most highly sensitive of all, are irritated.*

Thus the disease breaks out, and, as when a troop has been raised to which the gate is opened, so it rushes on.

462. *When the evil aroused by reason of these causes breaks out, the universal cerebrum intensifies and assembles all its forces for the purpose of dispelling it. For a sharp point pricking any one part of the cerebrum makes the whole to contract, just as is the case with a nerve, a muscle, a membrane. For every single part, constricting itself for the purpose of bringing aid, exterminating the vitiation and escaping death, shuts up the exit, or else expands the narrow pathways, urges and exasperates the moving [fluid], and so, diffuses the convulsion; thus the whole cerebrum labors and seethes with vertigo. Especially, however, do the associate and neighboring parts act thus; and so all the fibres, and consequently the nerves and muscles that depend on the fibres. For the medullary fibres of the cerebrum flow together in various ways from the whole cortical circuit towards the centrum ovale, and again and again run together before separating. Hence the pricking of one fibrous congeries excites many muscles in the body into simultaneous paroxysms. By reason of a confused cerebral agitation of this kind the cerebellum also is deprived of all power of acting, which effect results as often as the cerebrum acts from itself; for when the one acts the other suffers, thus each is alternately in sleep and in wakefulness. Moreover, also, where the action of all the parts is confused, there is no action; for one fibre acts against another and one muscle against another. Therefore the unhappy sufferer is thrown prostrate, he beats the ground, his mouth is tightly closed, his respiration interrupted; but with the interruption of the respiration the fury goes down, and the anger of the otherwise intractable cerebrum subsides.*

463. *The resultant effects are manifested in the nerves, muscles, glands, vessels, the circulations of the blood and spirits, and the chemistry of them all; but especially in the cerebrum; whence arises dullness, stupor, wandering of the memory, foolishness, paralysis, apoplexy and many other ills.*

CHAPTER X.

CONVULSIONS, SPASMS, TETANUS, TREMOR, ETC.

464. *The leaders of the medical art have not yet distributed all the varieties of convulsions into their genera and species, and still less have they designated each species with its own proper name; for many convulsions appear to run a similar course, but by diligent investigations one comes to a knowledge of their nature, and of the source whence they take their origin. There are some that descend from the cerebrum, some that have a nearer origin, that is, from the nerves; and there are some that originate in the muscles themselves, namely, from the state of their motor fibres, membranes, tendons, aponeuroses. There are some also that trace their origin to the arterial and venous vessels flowing into the flesh of the muscle. Consequently there are convulsions that are to be referred to paralyses, to apoplexies, to epilepsies. Those therefore who wish to reduce all convulsions to one only of the above mentioned diseases, would seem to be hallucinated. By reason of the variety of species the learned have made a distinction between febrile convulsions and the other or ordinary varieties which recur at stated alternations or else are rigidly permanent; and also those which invade a single muscle, or a single joint or member. Hence the names, spasm, tetanus and so forth, all which are to be treated of.*

FEBRILE CONVULSION.

465. *Febrile convulsion is so called because it is a concomitant of fevers, and arises from the same causes, that is to say, from causes which obstruct the arterioles leading into the substances of the cortex; for the cortical gland is entirely dependent on its arteries; from them also it derives its essence which it transmits into the fibres. On this account the state of the fibres and consequently of the muscles is deduced principally from the state of the blood. Therefore, if the blood be gross, hard, insoluble, concreted into ramenta and fibres, viscous, not easily separable from its serum, the arterioles near-*

est to those glands are stopped up. Thus the glands are deprived of their essential and vital juice, and either they lie half dead, or else they are filled up not with their own fluid, but with some other elementary. Such fluid, however, is not adapted for running through the medullary and nerve fibres; thus neither is it obsequious to the will of the mind; but it becomes adherent, and at the same time variously wounds and wearies the tunicles of the fibres. Hence convulsions from an internal cause. Convulsions come in like manner from an external cause when the cortical glands are beset round about with a tenacious, and, as it were, glutinous excretion, so that in their little spaces they are unable to reciprocate their animations; this also is an effect of febrile disease. That most highly pure humor that runs through the stems which weave the tunics of the cerebral arteries and which, in the preceding pages, we have called vessels emulous of the fibre,—stems on which the cortical glands immediately hang,—is also a usual cause of convulsion; for there is great poverty of this humor in febrile heat, where it lies imprisoned in the serum and blood nor can be extracted therefrom so long as the globule of the red blood remains hard and insoluble; neither, in such case, is there any kind of humor exuded between the pia meninx and the arachnoid tunic, and with the drying up of this spring the interstices between the fibres are deprived of their unguent. It is clear from the anatomy of the cerebrum that the cortical glands which correspond to the most active muscles in the body, are furnished with their own beds or arterial trunks in the cortical substance itself, and with receptacles in the medullary substances, in order, namely, that from them they may draw their supply according to the degree of their activity. These receptacles, when filled up with crude and viscous blood, can bring no help to the beginnings of the fibres, and therefore the medullary and nerve fibres, and finally the motor fibres of the muscles, are deprived of their motive spirit; hence arises convulsion.

CONTRACTION.

466. *Contraction, also called convulsion, draws its origin, not immediately from the cerebrum, but from the nerves* *themselves, or from the bloodvessels on which the muscle depends. For whatever obstructs the passages or pores of the nerve, and whatever obstructs the arteries which flow into the muscle, is the cause of this kind of convulsion. A nerve is obstructed by a vitiated, gross and over-tenacious humor sticking between its fibres and between its fascicles of fibres; for the fibres, thus rendered compressed, inert and impotent, cease to act into the muscle. Such humor springs either from its fountain, that is, the cerebrum; or from its arteries which run in abundance through the interstices within the nerves; or the humors are the remains of diseases of a vitiated blood. In the nerves or in the ganglia, cavities are thus formed which in their movements are stuffed with ichor, and this, when collected, compresses the fibres themselves, and when bursting out, relaxes them; hence arise alternate convulsive motions. Contraction is called* TONIC CONVULSION *when part of a membrane or muscle becomes rigid and there is danger of it remaining in this state. A similar effect results also if a nerve is compressed extrinsically, ulcerated, cut, stretched; and so likewise an artery. The cause of the convulsion may also be present in the muscle itself by the injuring of its nerve and vessel; that is to say, when it is inundated with blood or inflamed, rigescence occupies its motor fibre, membrane, tendon, aponeurosis.*

SPASMS AND TETANUS.

467. CYNIC SPASM* *is a like convulsion,—arising from the causes mentioned above when treating of febrile convulsions,—in one hemisphere of the cerebrum or in one part of the hemisphere, especially of its upper lobe. For it is a distortion of the mouth; sometimes also it drags with it the eyebrows, nostrils, neck. It is called* EMPROSTHOTONUS *if it moves the shoulder-blades from their natural position;* OPISTHOTONUS† *if it invades, twists and hardens only some individual part or member. It is called* TETANUS *when it is universal; and it is then a species of epilepsy.*

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*Canine convulsion.

†Emprosthotonus and opisthotonus are derived from Greek roots signifying, respectively, "bent forwards" and "bent backwards."

TREMOR.

468. TREMOR *or* TREMULATION, *as of the hands, head and other parts, and also as occurring in decrepit subjects, arises from divers causes, such as:* [1] *Defect of the spirits, extinction, stupor, torpor, sleep of many of the cortical glands and fibres of the cerebrum so that only few of them are voluntary agents which shall sustain the muscle.* [2] *Too great relaxation of the same; for with the loosening of their tension the fibres, impotent of action, lie down without law and order; for which reason there are interposed in the medulla of the cerebrum spurious glands, like piles and supports, which may restore to them their tension; so likewise in the two membranes, the pia and dura mater, the sinuses, and everywhere in the body.* [3] *A like relaxation in the nerves, that is to say, a relaxation of their ligaments, of the tunics covering the fascicles of fibres and the nerves themselves, and thus of the fibres; which latter flow along like stragglers, part of them lying extinguished and part being left to itself without any common dependency and relationship; a like thing then happens in the muscles and limbs, which, therefore, begin to tremble. The causes of the diminution of the spirits and of the relaxation of the fibres, are, however, many, such as the excessive use of venery, several kinds of intemperance, preceding attacks of paralysis, apoplexy or epilepsy, long-continued intermittent fevers, frequent swoons, old age, etc., etc.*

STUPOR, TORPOR, AND SLEEP OF THE MEMBERS.

469. *These diseases arise* [1] *from compressed muscles, vessels or nerves so that the joints are deprived of their bloods which are their several forces and potencies;* [2] *from freezing;* [3] *also from the causes which give rise to convulsions, for they exist in convulsions.*

HICCOUGH.

470. HICCOUGH *is a species of alternate convulsion. It is believed to be an affection of the diaphragm; but, while the diaphragm sustains the lungs, it does not enjoy the power of* *compressing and dilating them, for this is the office of the intercostal and several other muscles. Hiccough, however, seems to be an affection of the œsophagus where the latter is united to the trachea; when the œsophagus palpitates, the air is then drawn in with great force in order that the breathing-path of the larynx may not be occluded. Hiccough arising from cold, and from food imprudently conveyed into the gullet, also from weeping and other causes, does not of itself easily stop.*

SNEEZING AND COUGHING.

471. SNEEZING *is a high elevation and sudden compression of the whole cerebrum and cerebellum; and it is a natural means for the dissipating and scattering of humors, and for the expelling to the exits constructed by nature, of those phlegms which stop up the beds, interstices and meninges of the brains,—especially if they beset the cribriform plate,—as is confirmed by actual experience. It arises also from an irritation of the olfactory nerves, the fibres whereof are ramified around the whole cerebrum. The lungs which animate synchronously with the brains, likewise, at the same time purge their bronchia and cells.* COUGHING *is excited from a similar cause, but in the lungs.*

YAWNING.

472. *Yawning is a gentle elevation and erection of the cerebrum to prevent it from falling into sleep. For when the animus grows languid, and no motion thereof expands and wakens the cerebrum, the latter naturally collapses into a state of sleep, and the folds mutually fold together, and, commencing from the lesser folds, begin to cohere. This is guarded against by such an elevation; just as in the time of early morning when the several parts are to be unfolded.*

CHAPTER XI.

MELANCHOLIES, DELIRIUMS, MANIA, INSANITIES, LOSS OF MEMORY, TARENTISM, ST. VITUS' DANCE, ETC.

473. *The diseases whose causes I now commence to explore are diseases not only of the body but also of the animus and of our mind which is called rational,—such diseases, namely, as mania, insanity, tarantism and the rest. Thus they are diseases not merely of the red blood but also at the same time of the purer or prior blood, that is, of the animal spirits which run through the fibres. Hence, these diseases very closely touch the influx of the soul into the sphere of our understanding; and those who make judgment respecting the different causes of such diseases, affections, deliriums, from the visible blood alone, treat a sublime matter in a very crude way, stopping only in the threshold of effects, and when they think themselves to see causes, seeing only causates which they seize upon as causes. Consequently, for the thorough investigation of these diseases, it behooves us to enter more deeply into the inner recesses of animal nature; and then, at the same time, we shall be persuaded not only that there is a real influx of the soul into its body by means of the organs of the internal senses, that is, by means of the cerebrum and its cortical substance; but also that the soul is able to flow into its body in no other way than according to the state of the organic substances,—a truth which no one will call into doubt if only he deigns to contemplate causes from effects, or things prior from actual experience.*

474. *But preceding our enquiry, it is necessary that certain theorems be premised which may serve as the premises of the conclusions to be reached. Namely:* [1] *That the cortical substance is that to which, by means of fibres, external sensations refer themselves; or, that there are as many little internal sensories, or little as it were eyes of the intellectual sight, as there are such substances. Thus, that the cortical cerebrum is the verimost common sensory and likewise the common voluntary motory. Consequently, that the cortical substances* *are those prime organs into which the soul inflows with her light, the effect whereof is understanding, thinking, judging, willing; for if these organs are in any way disturbed from their natural state, form and situation, the understanding, the memory, and all that faculty which is called internal and truly human, suffers and sickens.*

475. *Since each cortical substance is a little sensory and the symbol of our understanding, it follows,* [2] *That all, taken together, constitute, as principal parts, the cerebrum, and produce something common which cannot be called the understanding. For that which is proper to the part is prior, superior and more perfect, while that which is proper to the parts taken together, that is, to the whole, is posterior, inferior and more imperfect. Therefore, that which is proper to the cortical substance is prior to that which is proper to the whole cerebrum, superior and more perfect. Consequently, to the cerebrum in the concrete cannot be attributed understanding, thought, will, but only a certain inferior power, such as apperception, imagination, cupidity. The former are properties of the intellectual mind, but the latter of the animus.* Confer the Transaction on the Fibre, n. 306, 307.

476. *This also must be known, namely,* [3] *That the vessels of the red blood, ramified into the minutest capillacious vessels finally germinate the cortical glands, which hang upon them like clusters of grapes from the shoots of their vine; and that from these glands proceed fibres which, in the cerebrum, are called medullary and, when continued in the body, nervous. These fibres, together with bloodvessels, construct the motor fibres in the muscles. Thus the motor fibres have respect to the cortical glands of the cerebrum as their origins which through the fibres transmit to them their animal spirits.*

477. *Moreover,* [4] *That the red blood, which is the seminary and treasure-house of all things in its kingdom, contains within it the purer blood, which is the same as the animal spirit and which breaks out from the resolved globule of the red blood and is transmitted into the cortical gland and through this into the fibre. Likewise, that elsewhere also, that is, through the vessels emulous of the fibre,* respecting which see the Transaction on the Fibre, chapter ix [nos. 168-187] *a certain most highly pure serum is transferred into the same cortical gland, that it may serve as the matter from which may be elaborated and with which may be mingled the said spirit or purer blood.*

478. *Furthermore also,* [5] *That the cortical gland is affected according to all the nature of that fluid which runs through it and is thereby transferred into the fibre; scarcely other than as the sight is affected by every variety of the forces or modifications of the ether; the hearing by every variety of the modulations of the air; the taste by every variety of the parts that touch the fibrillæ of its organ; and so also the smell. But in the cortical gland the effect is more sublime because its sense is purer, superior, more perfect, as also are the substances and the forces that affect it.*

479. *And finally,* [6] *That the cortical glands in particular and the cerebrum in general are able to undergo, and do undergo, an infinitude of states, or an infinite number of changes of state; that is to say, according to all that cause and variety of forces and forms which flow in and by which they are affected. As is the state of the cerebrum such is the state of the animus in the cerebrum; and as is the state of the cortical substance such is the state of the mind,—into which, the soul, when it flows in, can operate in no other way than according to its state; just as with the eye, namely, as is the state of the eye such is the sight,—although the ray or the solar light flows in in one way only; or, as is the state of the object illuminated such is the variegation of the light,—whence arise such varieties of color and shade. There is a similar ratio in all things in universal nature.*

480. *Each of the above propositions has been treated of in our Transactions, and from the little experience that was adduced we established that such is the nature of the cerebrum and that hence comes its faculty of sensating and understanding; but this will be still further confirmed by an infinitude of experimental testimony. Meanwhile, without these premises we labor in vain when drawing conclusions respecting the causes of the diseases which are the subject of the present* *chapter. The diseases themselves shall also add their own signs of confirmation.*

MELANCHOLY.

481. *Melancholy, regarded in itself, is not a disease, but is a temperament, styled melancholic, of the blood. Medically speaking, it is a sickness of the animus and body and sometimes breaks out into species of delirium and mania. But its nature, as it is in itself, is known from the character of the person affected by it. He is obstinate and tenacious of purpose, and in his meditation, stubbornly clings to certain objects and to them alone. Hence it follows that his nature is not what it is taken to be by virtue of the melancholy, but rather by virtue of his application and determination. Thus, if he be a friend he remains one; if an enemy he is a perpetual enemy. If elated in animus he falls into laughable pride; if ambitious in mind he is externally humble, frequently sordid, but interiorly puffed up. He is stern with harsh haughtiness against all who do not feel as he feels. If envious he suffers anguish and becomes livid; if angered he is disturbed and falls into dementia. For the most part, he is averse to external delights; loving solitude, he places no value on society except as a means of obtaining the fulfillment of his purpose. He is perspicacous in ingenuity; he is strong in judgment if he takes glory therein, for he is obstinate and vehemently insistent. If not well instructed he makes up dreams and phantasies which he thinks to be so many truths. If magnanimous he is intrepid, fearless, brave; if pusillanimous he is timid, foolish, avaricious, ever anxious about the future, loving himself and detesting all else. Thus among those who are afflicted with melancholy are the highly honorable, heroes, those born to the administration of the highest affairs, the industrious, the vigilant, the constant, the unchangeable, the square; among them also are the wicked, the profligate, those deeply steeped in crime, those bereft of all honor. For they all obstinately cling to the principles they have acquired. For the most part they are sad, sorrowful, spiteful, absent-minded, old before their time. The opposite of these are those who are of a sanguine temperament; for they are changeable, tractable,* *distrustful of themselves, prone to cupidities, lovers of delights. They are society itself, as it were; in genius like women,—by whom they are praised; by men they are censured, by melancholics despised; they are men of the present age, but not of the ages that have gone before.*

482. *There are divers origins of melancholy, and thus, relatively to their causes, divers species. There is sanguineous melancholy, atrabiliary, outmost, belonging to the body. There is melancholy of the animus, of the animal spirits, more purely sanguineous, interior, belonging to the cerebrum; this is called sadness and anxiety. There is melancholy of the mind; this is properly human, supreme; it is a species of hatred of the world and of life. There is melancholy of the soul; this is spiritual, as it were outside ourselves, and is properly conscience which causes remorse and agitation. These four are distinct in origin and nature: nor is any of them to be called melancholy except the sanguineous or corporeal,—unless indeed by analogy. Nevertheless one so excites and produces the other that they coexist, and a melancholy, in appearing to be of one species, imposes even on the skillful. For black and bilious blood excites grief and sadness of the animus, this excites a superior grief in the mind, and this an evil conscience, or hell. So also the reverse; for an evil conscience produces hatred of self and torment of mind, this produces anxiety of the animus, and this a bilious blood. But all four must be well discriminated; for medicine must be prepared for each one according to the causes. We dispel effects in vain if the cause and root of the disease remains. If the blood is concerned in the cause it must be cleansed; if the animus, its sickness must be dispelled by changes and delights, and by such things as emend the purer blood; if the mind, the very desires, hope, principles must be alleviated. If the cause is spiritual, the medicine is theology from the Sacred Scripture; and if there be mingled with it a natural cause, it is to be remedied by means of sciences which apparently explain the mysteries of faith.*

483. *The real cause why the one effect produces and excites the other, appears in clear daylight if we consider the influx*

of the red blood into the purer blood, and its transflux through the fibres and recomposition into red blood; that is, if we consider the circulations, which are three and distinct, and of which, nevertheless, the one inflows into the other,—which influx we have called the CIRCLE OF LIFE. Confer the Transaction on the Fibre, chapter xxvi [nos. 319-327]. *Or, it appears also in clear daylight, if we consider the connection of the bloodvessels with the medullary fibres by means of the cortex. All these matters become manifestly clear from the anatomy of the brain, when this anatomy is opened up all the way to its causes.*

484. *In true melancholic diseases the* RED BLOOD *is harder, insoluble, spurious mingled with genuine, concreted with fragments of bile, antiquated, obsolete and livid such as is ejected into the gall bladder and from thence through the feces, menstrua, hemorrhoids. Such blood cannot but tenaciously stick in the minute arterioles that pour immediately into the cortical substances. The* PURER BLOOD *or animal spirit which runs through the fibres, is hence rendered sluggish, cold, somewhat hard, not easily soluble,—just as in the case of the red blood; for the fact of the latter blood being too hard, originates, in this disease, from a like nature of the purer blood of which it is woven. The* CORTICAL SUBSTANCES *themselves wherein our soul actuates its rational mind, derive thence a similar nature, namely, that they are somewhat hard, tenacious, not easily mutable in respect to their state of expansion and constriction, but sluggish and stiff in action. This is the reason why melancholic subjects are fixed in one object of thought and are tenacious of purpose. For it is the easy mutability of the accidental state of the cortical substances, and thence of the cerebrum itself, that causes the presence of perception, conclusion, determination; and this never obtains if the organs themselves are overly hard and sluggish, and if the blood sticks in its tracks both in the vessels and in the fibres; for as is the state of the cortical substances such is the state of the fibres, and hence such the state of the common sensory, of the organs of the external senses, and of all else that depends on the fibres.*

485. *But the question is asked, Whence comes sanguineous melancholy? We answer, From all causes that render the blood* *too hard, such as, from retardation and inhibition of the universal circulation, that is, of the circle of life. For if the red blood accomplishes many circles and is not resolved nor rejected, then it grows hard, antiquated, and obsolete. This is caused by nourishment that is crude, terrestrial, too much cooked and boiled and thus dead; by all the causes of indigestion, whence arise the souring of the foods in the stomach, rancidity, depravation of the chyle; by a scanty besprinkling of the saliva and gastric juice, and an over-large besprinkling of the pancreatic and hepatic juices and the bile, in which case the chyle is carried through the thoracic duct or insinuated immediately into the veins, crammed with these juices. It is also caused by the occlusion of the excretory passages for the feces, urine, menstrua, hemorrhoids, sweats, and Sanctorian perspiration. Moreover, it arises from an excessive excretion of innocuous lymphs; from wakefulness, whence comes feverish blood; from excessive sleep, whence comes grossness of the blood without fever; from poisons, which harden the blood. Such constitution of the blood, or of the ducts that serve for its commingling, resolution, separation, extermination, is also hereditary; thus melancholic subjects are also born.*

But the genuine causes of melancholic blood are: Too scanty an afflux of the purest blood, which is produced ever new in the cortical substances; causes arising from a failure of the variation or mutation of the state of the cortical substances; also from a failure of transpiration through the purest pores of the cuticle, by which failure the blood is deprived of its serum or vehicle. The pellucid globules of the blood are thus rendered over-sluggish and tenacious,—as is the case with the old and the decrepit who, for the most part, are of a melancholic nature and are somewhat dull in respect to the faculties of sensation. But there is a connection of all the causes.

486. *But whence comes melancholy of the animus, or anxiety? When not immediately from the blood, it comes from almost all the sicknesses that are attributed to the animus, such as sadness, grief, anger, envy, fear and other affections which we have in common with brute animals. These affec-*

tions all spring from their own causes, to enumerate which, would be too prolix; in civil society there are new incitements every day. As was said above, these causes flow into the bloods, and indeed, immediately into the purer blood or animal spirit. This they render overly sluggish and tenacious; for all the opposite causes, such as gladness, love, joyfulness, dilute it and keep it agile. Thus one cause flows into the other, like one blood into the other through the circle of life. Sadness thickens the blood; anger excites the bile; fear induces cacochymia, and closes and empties the ducts; envy commingles bile with the blood, whence arises lividity, emaciation, blackness of face and blood. The effect is the continual effect of the cause; the cause produces the effect but the effect excites the cause. Therefore as is the blood such is the animus, and as is the animus such is the blood.*

487. *But whence is the state of mind that produces an effect like this? There are many affections proper to the mind, which, regarded in themselves, have nothing in common with the sicknesses of the animus; such as all desires and cares for the future, self-providence, divers loves of ends, intense studies, perverse principles of morality, and many other things that are not found in brute animals. But because we mortals for the most part indulge the passions of our animus and the pleasures of our senses and body, the mind is swayed by its animus; hence, without some special investigation, it is difficult to discriminate these desires of the mind from the affections of the animus, although they are most distinct from each other. Let us take the desire of some future happiness which we contemplate with assiduous mind and which is sometimes nourished by present hope. If we are suddenly deprived of the hope, we fall prone into a kind of despair, nay, into hatred, either against the one who causes this deprivation or against ourselves; this straightway produces sadness of the animus, and, by this means, a melancholic blood. So likewise in the other cases.*

488. *As regards the supreme cause of all, which we have called the spiritual cause, and the evil conscience arising there-*

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*See n. 445, note.

from together with its torments, this cannot arise immediately from the rational mind unless that mind has been instructed in sacred and divine laws and commandments; and unless it acknowledge the soul, its immortal life, heaven, blessedness, God the deliverer; otherwise it is not spiritual but natural. Wherefore, it traces its origin to the soul, which is spirit, and to the Divine Spirit, which notes, represents, inflows, withdraws. Flowing from these principles this conscience is called temptation, and as to its origin carries nothing in common with the causes mentioned above and which, in themselves, are posterior. Moreover, descending into the rational mind, from this into the animus, and from this into the blood, it also perturbs, inverts and robs the whole animal organism. They who deny this its origin and assert only a posterior origin,—it is indeed also excited by the blood,—are either ignorant of, or else tacitly discredit, the soul, its immortal life, heaven, blessedness, hell, God the deliverer; and their conscience is thus either nil or spurious.*

THE HYPOCHONDRIAC DISEASE.

489. *The melancholic disease described above has also the vulgar cognomen the hypochondriac disease, also the hypochondriac affection, and it is ascribed to some juice or* VAPOR† *which is called melancholic. Such vapor is believed to rise from the stomach immediately into the brain and to constrict and perturb its organism or sensory. The reason is, because the hypogastric region, that is, the stomach, mesentery, omentum, pancreas and spleen, are affected with a certain dull pain and a sense of constriction which is immediately followed by anxiety*

**Vindex.* The word means Defender, protector, deliverer, vindicator; and also Avenger, punisher. It well illustrates that class of words whose meanings extend from opposite to opposite according to whether they are viewed in relation to good or to evil.

†This word is capitalized by the author perhaps in connotation of the name "the vapors," colloquially given to hypochrondria; other colloquial names are the blues, spleen. low spirits, and, in the French, the imaginary or English malady. It is characterized by illusions and inordinate anxiety in respect to the personal state of health.

sometimes breaking out into wailing or a species of delirium; moreover the stomach is kept constipated with crude and earthy dregs and coagulated matter, with which also are intermingled the biles.

490. *But the proximate cause of this disease or affection is an obstruction of the chyliferous and lymphatic vessels,—both those which discharge into the left subclavian vein through the mesentery and the thoracic glands and by way of the thoracic duct, and those which spring from the pancreas, spleen and other viscera situated in the hypochondrium, and irrigate the blood with a perennial fount. This lymph mingled with animal juice, being the purest of the lymphs, is drawn up towards the cerebrum and delivered to the cortical glands, that it may be remanded into the fibres,—all, that is to say, except the abundant supply that is exhaled between the arachnoid tunic and the pia meninx and is transferred to between the fibres.* Confer the Transaction on the Arachnoid Tunic, chapters ii, iii, iv, v [nos. 342-365.] *Such lymph is poured out in immense abundance from the viscera under the diaphragm, especially from the spleen, to say nothing of the other viscera whose lymphatic vessels flow together into the thoracic duct. When the cerebrum is deprived of this lymph it straightway labors and is anguished; for the very fibres become dry and contracted, and, at hand and urgent, stands mere blood with a sluggish and coldish serum, and which is not resolved, nor, when resolved, can enter into the penetralia of the corticals. This lymph is, as it were, the chyle of the medullary and nerve fibres, just as that juice which is carried immediately from the stomach, is the chyle of the veins and arteries.*

491. *Therefore the cause of the hypochondriac disease is the cessation of the circulation of the lymph called the lymph of the thoracic duct. The immediately resulting effect redounds upon the cerebrum, for this is straightway deprived of its vital juice on which live its sensory organs, that is, the cortical glands and the fibres. Hence comes a change of the state of the cerebrum, that is to say, a difficult elevation or animation of its corticals with an unexpected constriction; or else, the influxion of a non-vital serum, a useless drive of the red blood,* *and a vain solicitation without any conveying vehicles. Hence arises a universal anxiety,—for the whole kingdom labors. For any other lymph than that which is most select and is gifted with animal spirit can hardly enter those subtle passages. Therefore it is this lymph, together with the better blood, that is continually drawn towards the cerebrum. Thus this disease is not the rising of some vapor from the stomach towards the cerebrum; for whatever grossness is in the chyle or is brought into the blood is not taken into that superior region which demands lighter things.*

492. *A blood that, of itself, is hard, not readily soluble, not genuine, that is, a melancholic blood, demands an abundance of such fluid and swollen lymphatic vessels, in order that its defect may be supplied by adventitious aid, in lack whereof a* MELANCHOLY *breaks out which is then called* VAGUE *and* WANDERING.

493. *The lymphatic vessels and chyliferous ducts are closed by causes in the body and by causes in the cerebrum, that is, in the animus. The causes in the body are crude, earthy, dead aliments and viscous matters; and the superfluity and retention of these in the stomach and intestines. They are also produced by condensed air, colic and acute pains; that is, by flatulence which distends the stomach and intestines, whence come eructations and vomiting through the fauces. Other causes are, an abundance of bile which overloads the chyle; a lack of saliva, and of the œophageal and gastric juices; the indigestion thence resulting, and every cause of indigestion; a laxness in the structural substance of the stomach and the cessation of its vermiculation and peristaltic motion; and many of the conditions described above when treating of melancholic disease.*

494. *But causes in the body do not produce this wandering melancholy, or the melancholy that returns by alternations, unless the blood in itself be melancholic, that is, be of the quality described above,* n. 484. *Hence the animus has a proclivity to sorrowful emotions or mutations; and therefore there are causes in the cerebrum or animus which directly concur. These are what produce the disease; but they are excited by causes* *in the body, and by causes outside the body. By* CAUSES IN THE BODY, *namely, by all the causes recounted just above, such as flatulence, sourness, rancidity and crudity of the food, and the other causes. There is a wonderful correspondence of the state of the stomach with the state of the brain, or rather, of the cerebellum; for the villous tunic of the stomach and its extended fibres announce to the cerebellum as by a certain sense, the state of their viscus; thus the cerebellum is affected,—just as the cerebrum is affected by sensation and pain in the skin; hence the latent and bodily causes of the emotions of the animus; and consequently the constriction of the ducts, both lymphatic and salivary, and the unloading of both kinds of bile. By* CAUSES IN THE CEREBRUM OR IN THE ANIMUS,*—which have been enumerated above,* n. 456,*—arising, namely, from sadness, grief, anger, envy, fear, etc., that is to say, from causes outside the body; as sadness arises from misfortune, losses, death, injuries, change in the love of parents, of friends, and a thousand other causes; so likewise with fear and the other sicknesses* [*of the animus*]. *When these are excited the circulation of this lymph is at once stopped, the stomach is constricted, the vessels of the mesentery are stopped up, and into the closed thoracic duct no lymph can flow in from the other viscera. Thus it is the animus that so suddenly constricts them. It is also the animus that expands them, as, for instance, gladness, joyfulness, the pleasantness of society, free conversation and the like, while the contrary affections present contrary effects; for the body acts and suffers according to the state of its cerebrum. From this it is apparent how greatly merriment and amusements contribute to the digestion of the foods, the dispensation of the chyles, and the promotion of the circulations.*

495. *There are, besides, other ducts still more subtle which lead immediately from the stomach, lungs, nay, from the universal external skin of the body towards the cortex of the cerebrum and cerebellum; these we have called vessels emulous of the fibre, or corporeal fibres. These in like manner are opened and closed according to every affection of the animus. But of these we shall treat elsewhere.*

THE HYSTERICAL DISEASE.

497.* *The hysterical disease is also classed among melancholic diseases; for it is a suffocation of the womb and its ducts, which extend to the cerebrum and to the pia and dura meninx thereof. Thus a parallelism may be instituted between this disease and the hypochondriac. Hence a sharp pain, called* CLAVUS HYSTERICUS,† *is felt in the pericranium.*

498. *That there are frequent communicating ducts between the womb and the cerebrum and its meninges, is a conclusion drawn not only from the fabric of the womb itself, but also from the passions of gravid women, from the growth and nutrition of the embryo, from the influx of the maternal imagination into the little body of the infant, from the erection of the Fallopian tubes and their fimbriæ, from the state of the ovary and of the retained menstrua, and from many other phenomena.*

499. *The path that leads from the uterus towards the dura meninx and at the same time towards the pericranium is along the periostea, through the tunica vaginalis of the medulla spinalis, towards the great foramen of the occiput, and thence to both of the periostea, namely, the external or the pericranium and the internal or the dura mater. That this path is, as it were, the royal road for a certain humor which, finally, is either exhaled or goes off into the capillaries, will be demonstrated in its own place from many considerations.*‡ *Therefore, from causes belonging both to the body and to the animus,*

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*The Latin editor notes that in the MS. "between the paragraphs numbered 495 and 497 respectively, is found the number 496 but without any paragraph appended thereto. Nor (he adds) can we account for the fact that the numbers only are irregular while the series of the subject remains uninterrupted." It would seem as though the author had intended either to add another paragraph on the subject of hypochondria, or to add another subsection with a separate title. We note that the repetition of n. 504. below, balances the present omission.

†Clavus Hystericus (*clavus*, a nail) is a headache, found particularly in hysterical women. A most acute pain is felt in the front part of the head as though from a piece of ice or the boring of a nail; hence the name.

‡See the little treatise THE PERIOSTEUM, included in the work on Generation, p. 362 *seq.*

when the uterus is suffocated and its ligaments, tendons, and connections with the bones and periostea complicated,—a circumstance which may happen after childbirth,—the above mentioned circulation ceases. Hence results an effect that redounds upon the pericranium,—from which arises clavus hystericus; and upon the dura mater,—from which arises difficulty of respiration, dull pain, and anxiety.

MANIA.

500. *Mania is the last stage of melancholy; for the blood of a maniac is exceedingly hard, almost insoluble, sharp, livid, black and badly coherent with heterogeneous matters; genuine globules float sparsely in its serum; it is born but not unborn. Being thus copious, it is, as it were, bile and bitterness. The purer blood, the globules whereof are naturally elastic, divisible, flexible, yielding, is likewise tenacious, coherent, not easily yielding, fibrous, and thus not of its own nature active, unless from some stronger impulse, because not passive. Hardness cannot indeed be attributed to it such as is attributed to the red blood, but only tenacity,—which tenacity is its hardness as compared with its own nature of extreme flexibility. Thus in maniacs the red blood is radically sick; for a compound derives its nature from the quality of the component parts.*

501. *As is the blood such is the* ARTERY; *for the tunic entirely accommodates itself to the nature of its blood. Hence it also is somewhat hard, and still more is this the case with the least or capillary tunic which is next to the cortex. To it sticks a blood that is indocile as regards passivity, is blocked up, is not capable of motion in one direction or the other, and sits unmoved unless urged by a stronger force and compression. The common arteries or little trunks are blocked up with a similar blood, and become turgid. In like manner the* FIBRES *which are smeared with a tenacious purer blood or animal spirit. The cortical* GLAND, *being midway between the arteriole and the fibre, must necessarily be beset with a similar blood as the fibres; and therefore these glands also become rigid, that is, they offer obstinate resistance to changes, and respire illy and only with sluggishness and draggingly. That* *the state of the cerebrum is such is a fact taught by actual inspection of corpses; for the cerebrum of maniacs is seen to be "dry, hard, friable, yellow in its cortex, with its vessels turgid, varicose, and distended with a black tenacious cruor."* See Boerhaave's APHORISMS ON MANIA, n. 1121. *Similar also must be the state of the arachnoidal lymph and also of the lymph of the thoracic duct which partakes of the purer blood; hence the general friability.*

502. *The causes of the breaking out of melancholy into mania are all those that have been mentioned above in treating of melancholy, but sharpened to the highest degree. That is to say, there are causes in the blood, causes in the animus and also in the mind. Causes in the mind produce those in the animus, and causes in the animus produce those in the blood; but causes in the blood excite those in the animus and these those in the mind. Thus the superior causes are the genitors of the inferior, and the inferior are the exciters of the superior.*

503. *From the state of the bloods, arteries, fibres, corticals, in maniacs, in a word, from the state of the cerebrum, is judged the proximate cause of their fury, namely, the fact that the cortex, wherein the soul actuates its rational mind, remains almost immutable without a blink at the presence of affluent objects, and thus in a single idea of thought; hence dreadful imaginations and lycanthropia.* For the cortical glands are most highly exquisite senses, since taken together they are the internal sensory; they undergo accidental change of state according to every cause and variety of the forces and forms that flow in, or, they are affected according to every nature of the fluid that runs through them.* Confer above n. 478, 479. *For whatever is not changed according to the forces that rush in, that same neither sensates nor consequently perceives the form, harmony and disharmony of such forces; but it acts solely according to an impressed idea, whether appropriate or not appropriate,—and therefore is insane.*

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*A species of hydrophobia. The patient imagines himself to be changed into a wolf. The word signifies "wolf-man."

504. *Moreover, hence also comes the force and strength of insanity, in that the parts of both the bloods are not smooth and most evenly round, but are sharp, rough, and closely set about by sharp-pointed or sulphurous and volatile-urinous elements; for what is hard and tenacious does not dissipate the angular adhesions that flow around in abundance; thus spicula stand out everywhere. Consequently the blood globules, being also prickly, when they run through the arteries and fibres, and especially through the tender and sensile walls of the cortex, prick, ulcerate and wound. Hence arises sickness excited to the highest degree and even to insanity; and pain, not sensible as in the body but as in the mind; emotion and passionate violence; and persistent wakefulness.*

504 [a]. *These, however, are the causes of insanity but not of mania; for insanity is of the mind, while fury is of the animus, and maniacal action of both. We can be insane and yet not furious, and furious and yet not insane; the two can be separated and also conjoined. To be insane is to think, judge and will perversely; but to be in fury is to imagine dreadful things to oneself, to crave things unnatural, or to act contrary to every order and law of nature without any fear or horror. Although, in themselves, the two are distinct, yet it is not given to everyone to perceive them distinctly. Insanity is judged from the state of the corticals, but mania from the state of the whole cerebrum. Hence we must know what special property belongs to the state of the corticals and what special property to the state of the cerebrum. The special property of the state of the cerebrum is the situation, fluxion and connection of corticals, fibres, and vessels, whence its form and figure. That in maniacs the state of the cerebrum is a perverse one is a fact manifestly evident from the tenor of these same causes; for the arterioles and fibres, thus turgid and stuffed up with cruor, contract and become shorter; the cortical glands, suspended midway between their arterioles and fibres, are moved out of their natural situation and their connection with the neighboring glands; thus the harmony of consociation is lost, and consequently the mutual respect between the principal parts. Thus the state of the cerebrum is perverted and* *the animus is affected; hence arises fury together with insanity, that is, mania.*

505. *When the red blood sticks in its vessels and the white and purer blood in its fibres and in the cortical glands, the cerebrum labors with immense effort and with its entire forces to dispel that which obstructs; for it intensifies its powers* (animas) *according to the ratio of the resistance. The resultant effect is that immense strength is added to the muscles; for as is the acting force of the cerebrum such is the force of the muscles that depend on those fibres or forces. The rule is, Whatever state is put on by the corticals, the like state is diffused into the fibres continued therefrom, and consequently into the whole system woven of fibres and bloodvessels.* Confer Transaction II, n. 202. *This robust, bold, strong and hard quality is therefore noticed in the several joints, in the motion of all the viscera, nay in the sensation and the very speech and the articulation of the words.*

506. *Maniacal diseases can be distributed into their genera and species, for they are as many as are the subjects or cerebra. There are as many genera as there are natures of the blood, states of the corticals, both in themselves and in respect to their connection with their arteries and fibres, and states of the cerebrum, that is, natural inclinations. There are as many species as there are determinations to one emotion of the animus rather than to another; for there are determinations to anger, or to revenge, or to sorrow, or to love, or to pride, or to many emotions simultaneously; considered particularly, they are determinations to this or that species of anger, revenge, sorrow, love, and so forth.*

INSANITY.

507. *Careful distinction must be made between insanity and mania. Insanity is of the mind, but fury is of the animus, and maniacal action of both. Insanity is a perverse state of the corticals, but mania is a perverse state of the whole cerebrum.* Confer, n. 504 [a]. *There is hardly a mortal who is not in his own way insane. He alone is sane and acts wisely who worships God, thrice best and greatest, and by faith aspires to* *eternal bliss; and the wisest is he who regards not even this bliss, except as a consequence, but the glory of the deity as the principal thing. From this description of wisdom it is clear what insanity is, minor or major; for insanity has its minimum and its maximum, and consequently its degrees. What the insanity is, its nature and intensity, is known from the ends which the mind has in view and follows up. The further these ends recede or withdraw from the one and most universal end, the greater the degree of insanity, the greatest degree being when they oppose it diametrically; then they are carried away from wisdom, that is, from the deity, the beginning and the end of the universe, and are delivered over to themselves and their own insanities and to the devil.*

508. *This insanity however does not properly take the name insanity, because it is universal and is believed to be truly human, and indeed, of such nature that the world declares those to be insane who are not insane. But medically speaking, an insane person is one who acts contrary to accepted propriety and the customs of society, or, still more, who obstinately defends his own opinion against acknowledged truths and the judgments of a sound mind, and pursues it to the contempt and derision of the vulgar, that is to say, who, deranged and empty of mind, exposes himself to public sport. Such insanity is a perverse state of the rational mind and consequently of the cortical substances in the cerebrum. It arises from divers causes, that is to say, from causes above itself, from causes below itself, and from causes without and within itself. But it would be a lengthy undertaking to weigh the several origins, species and effects; nor do these have regard to pathology but rather to psychology. Pathology goes no further than the red blood and the purer blood, that is, no further than the body and animus, and hardly to the latter except conjointly with causes in the red blood and the body. Let it suffice that insanity of the mind is the interior and superior cause of sicknesses of the animus, and that delirium of the animus is the superior cause of diseases of the body.*

DRUNKARD'S DELIRIUM.

509. *Delirium arising from drunkenness is a species of wandering insanity; for the cerebrum becomes dizzy, the joints and feet totter, the head sinks uncertainly, the speech lacks point and wanders, the senses grow dull and not consonant with the internal senses, the imagination becomes fanatical, and that which is voluntary is dulled and delirious; as for the other symptoms, who does not know them? Wine, vapid wine,* spirits, fermented must, beer, nay, exhalations, are what produce it, and this by way of the gullet or stomach. Therefore it belongs to the blood, to the sensory and voluntary motory, to the cerebrum and consequently to the corticals; and it consists of an abundance of sharp-pointed and diversiform parts which when they are pushed through the tiny beds of the cortex and the little channels of the fibres, prick and tear them and rouse the substances into motions not their own. Therefore the cause of this insanity lies within the cortex; if it lies outside the cortex a like effect also results, but with a difference.*

510. *The state of the corticals is such that they actuate nothing of themselves and their own spontaneity, but stand ready to be acted upon by causes below themselves which flow in, that is, by the senses, the body, and the blood; to which several causes, the corticals are so open that as soon as they are acted upon they begin to act in a similar manner. Hence from perception of things sensible arises thought, from thought the forming of judgment, and from the forming of judgment will, which is the conclusion of the operations of the mind. The cortical substances are as it were intellectual eyes into which flow the light of intelligence from the soul and images or ideas from the field of the memory; not unlike as with the eyes of the body into which flow natural light from the sun and images from objects. Therefore these cortical substances, per-*

**Vappa,* wine that has lost its spirit and flavor. Blancart defines the word as meaning "a humor which brings neither pain, heat nor corrosion. and which by cooking or exhalation, has been deprived of all the virtue formerly within it."

petually illumined with intellectual light, behold nothing rationally until images and forms flow in from the memory and the senses. Meanwhile they stand ready for the influx, which latter is effected as soon as anything from without or below is represented, to which are associated related ideas so that one common idea shall stand forth. But when the cerebrum is inebriated, the blood drawn up thither is circumfused with an abundance of angular and diversiform, that is, of vinous, entities, so that the substances are no longer open to the influxes of ideas from the senses and memory, in order, namely, that they may put on suitable states in accordance with all those forms. From this comes a passion unlike the action, and an action unlike the passion, that is, disharmony, and hence delirium.

511. *This delirium is varied in subjects according to the causes that produce the inebriation and according to the states of the inebriate, hardly otherwise than is the case in mania and insanity. Dull minds, or languid and lax cortical substances, are stimulated into a better and more responsive life, while lively and expansive minds become sorrowful, or fall into passions, or grow furious. Sad and anxious minds refuse the influx, and the things that flow in beat in vain upon the walls of the corticals, collapsed and almost insensible. Joyful and happy minds become tremiscent at the presence of the tiniest points in contact with them. Subjects whose mind is enfeebled and their cortex ulcerated,—such as the sick, the melancholic, and the aged,—grieve and more quickly become delirious. Subjects in whom the circulation of the two bloods through the vessels and fibres is brisk, the discrimination of humors in body and cerebrum prompt; the chemistry of nature vigorous; who have an abundance of fluids, a fatty blood, cortical substances and fibres that are healthy and not thin but thick,—such subjects become inebriated more slowly. The other effects also can easily be learned from a knowledge of the causes. From the effects of inebriety is known the mind and animus of each subject.*

FEBRILE DELIRIUM. PHRENITIS.*

512. *Delirium is also usually a concomitant of burning and acute fever. In this delirium what the patients sensate they perceive differently; thus they do not think and judge like as they sensate, but perversely. The external and internal senses are frequently so dissentient that the patients dream while wide awake; see things not seen, and hear things not spoken; act without cause as if from a cause; pluck at feathers or flocks as if such things were actually present; pick off bits of wool; are terrified at their friends as if they were furies; see children as giants, and the things they meet with as spectres, to say nothing of other ghosts; they pluck at nothings and speak insanities.*

513. *Fever is a cause of delirium, the general cause being heat of the blood and its close unition with the serum. Hence the whole chemistry of the body lies destroyed; for the blood ought to float freely in its serum and to be separated in the arteries,—especially in those of the cerebrum where the blood-globules are to be resolved into their elements or constituent parts and to be passed separately through the lattice-works of the fibres. But this is now prevented by the copulation of the serum and blood; and nevertheless those little hearts, that is, the cortical glands, and an abundance of fibre, necessarily demand some juice that they may draw their breath and sustain the whole system. Hence in place of spirits they attract and absorb some thin serum stuffed with urinous spicula and sulphurous ramenta. Thus in place of animal spirits comes a guest of alien genius,—a guest which of itself is not fluid, nor compressible, soluble, animal, and still less vital; but is resistant, hard, sluggish, cold, and at the same time pungent and pricking. Such stranger-flow, unless commingled with a vital fluid, cannot be ruled by the cortex of the cerebrum, and does not fly at its nod to its ultimate bounds, that is, to the motor fibres in the muscles; but, unless continually thrust on, it sticks in its steps. Hence arises pain and impotence in the cerebrum, languor in the muscles, debility in the body, depravation of all the humors, and universal cacochymia.*

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*The Phrensy, inflammation of the brain, brain-fever.

514. *The substance of the cortex, and also the fibre, when traversed by a lymph of this kind, which is not its own or vital and which yet perpetually pricks it, is driven into motions not its own, lacerated with stabs, enkindled by a heat not of life but feverish, and finally becomes numb and stiffens itself against the stings; the cerebrum meanwhile in no way endeavoring by compression to disperse these ills. Thus an active state is put on not correspondent to the state of the organs of the external senses; nor is the mind passive in accordance with that which the senses act, nor the organs of the senses passive in accordance with that which the mind acts; for they do not apply themselves to each other. Hence arises febrile delirium and phrenitis.*

515. *The above is the state of the cortices and fibres. The other parts, becoming inflamed, grow rigid,—such parts, namely, as the meninges, both the pia and the dura, also the vascular portion of the cerebral medulla, and so, by connection, the tunics of the nerves and fascicles. Inflammation then also invades the optic nerve, nay, the eye itself and its tunics and humors, and also the ear and its tympanum and fenestræ. Thus the state of the external sensory itself is also perverted; hence a two-fold cause of delirium.*

PARAPHRENITIS.

516. *Just as febrile delirium and phrenitis invade chiefly the cerebrum, so paraphrenitis invades chiefly the cerebellum. That is to say, in place of the spirits and purer blood, a certain serum not of its own nature elastic, compressible, soluble, vital, but dead, hard, sluggish, beset with an infinitude of little saline and sulphurous daggers, is intruded into the cineritious substance and fibres of the cerebellum, and thence into the muscles, joints and viscera depending on these fibres, that is, on the par vagum and the great intercostal nerve; hence, from a like cause, there redounds to the several parts, such as the pleura, diaphragm, lungs and the parts of the abdomen, disobedience, a refractory force, impotence and torpor. The cerebrum and cerebellum hold the kingdom of the body divided equally between them, so that where penetrates a fibre of the cerebrum* *there also penetrates a fibre of the cerebellum; the one rules in the daytime, the other at night. Consequently, when the fibre of the cerebrum succumbs, the fibre of the cerebellum, now forsaken and almost deprived of companions, labors with immense effort to arouse the forces of the muscles.*

417. *Moreover, from a like cause, the meninges and the vascular substance of the cerebellum are inflamed and become rigescent; and with them the tunics of its nerves. Thus from a double cause there arises a resistance together with an acute sensation of pain, since the fibre of the cerebrum is living. This incredible pain is felt in the respiration and in all the acts which depend on the respiration; that is to say, in each one of them, and especially in the more vehement, such as coughing, sneezing, stretching, emission of the urine, unloading of the feces, vomiting; hence the effort to suffocation, and many other symptoms.*

LOSS OF MEMORY.

518. *In the several diseases, as in melancholy, insanity, fever and so forth, there are degrees between their minimum and their maximum; but nothing is included among the class of diseases recognized by medical men except what is in the ultimate degrees. So with loss of memory. There are some in whom the memory is feeble; some in whom it is wandering, returning only at intervals; some in whom, either by nature or from cultivation, it is very slight; and there are some in whom the whole memory suddenly lapses so that they return into the state of infancy. This latter stage of loss of memory is the first to be recognized as a disease; nor, until it has reached this stage is it given over to the care of a medical man but is left to the healer nature. In this stage the memory of the past has so perished that the patients do not remember the least thing, not even in respect to the words, speech and actions into which they have been initiated by use and cultivation. Except in regard to stature, body, and an infantile sucking and wailing, they are as it were unborn and reborn, since they have fallen into oblivion of everything; and this to such an ex-*

tent, that they are obliged to learn anew from nurses and masters the very rudiments of life and knowledge; that is to say, they commence life over again. From these considerations, rationally digested, you yourself, if you wish, may cast the votes analytically, and consider whether it is a case of the soul having emigrated from its body and another soul succeeding in its place, or whether the soul is one thing and the rational mind another. Any sane person will conclude that our rational mind is not the same as the soul, but that our reason can be perverted, become insane, nay, be destroyed together with its organism, the state of the soul still remaining entire. But these matters will be treated of in our psychological Transactions.

519. *Meanwhile, in order that we may know whence comes loss of memory, it is first necessary to know what is memory. In the whole study and pursuit of psychology nothing more wonderful is met with than the memory, nor anything more difficult of disentanglement. Its nature might indeed be expounded to the understanding of many persons, but not in a few words; for the commencement must be made from principles hitherto unknown. To expand our sails at this point is not advisable, but I will relate as much as may suffice for the intelligent.*

520. *Memory cannot be an image pictured in the cerebrum, or spread, one over the other, upon a tablet; nor can it be an impressed image laid up in little pockets from which it may be summoned for uses; this is diametrically repugnant to nature and reason. But memory ought to be a change of the state of some organic substance wherein the soul actuates its rational mind; thus, necessarily, it depends on the change of state of this organism, that images and the little modes of the senses are retained in the memory. But if change of state is the cause of memory we must enquire what is change of state. Speaking briefly, the state of the corticals and of the cerebrum is changed in divers ways, whether it be that those substances are expanded or constricted, hard or soft, active or passive, hot or cold, tremiscent or tranquil; naturally, whether they be gross or* *fine, consist of abundant fibre or of little, besides an intrinsic variety which is infinite. But to enumerate all the genera and species of the changes of state would be prolix. Meanwhile this truth is clear, namely, that the perfection of purer substances consists in their being able to undergo, to put on, and to suffer to be induced on them, every variation of state. Whatever therefore cannot change its state, that same is imperfect. The entities of purest nature are therefore most perfect, in that they are able to be accommodated to every change of state, and, in a moment, to run through the several states with such great variety that there is not the minutest phase of variety,—singular and universal and general,—that can possibly be thought of, to which they may not be applied. I know that I speak strange things, but what does it matter since they are true! Let us be enlightened by an example: The eye, which is the organ of sight, while grasping its objects and images, undergoes by that very fact, innumerable changes of state; that is to say, a different change for each species of color, harmony, disharmony; for each degree of shade and light; for each degree of distance, multitude, magnitude. For each one of these it variously contracts, expands, pushes out, draws in, turns, its pupil, iris, tunics, humors, retina; and applies itself to the object in such way that it receives and is affected exactly as the state of the object requires. This cannot be unknown to any one who pays attention. The like also happens to the drums, fenestræ and cochleæ of the ear; to the papillæ in the tongue and to the universal body from the diverse states of the things in contact therewith; who then doubts it of the cerebrum? From the organ of natural sight let us now pass to the organ of rational sight or of the ideas of the mind, that is, to the cortical substances which are the organs of the internal sense corresponding to the organs of the external senses, being so many little cerebra or so many minute eyes. Since these substances are entities of purer and more perfect nature it is necessary that they be able to undergo changes of state infinitely greater in number and perfection than can the eyes; that is to say, to be disposed to every influx and reception of images and* *modes from the external senses,—potentially in infancy and effectively in the following age. But the question is asked whether change of state can be the same thing as memory. I say that it is; for purer organic substances are apt of themselves to the putting on of every state, and the state is induced by influx from the senses, thus by use and cultivation; and a state that is induced, remains, and it returns just so often as there is a relapse and turning to it, that is, just so often as the mind or its organic substance, that is, the cortical substance, revolves and turns itself from that state in which it is, or into which it has been reduced, to all similar states. That which flows in is perceived or sensated; hence by the changes of state resulting from the state induced, thought is excited, from thought judgment, and so on. But these operations appear to be too physical, and therefore there cannot but be a doubt as to how that which is metaphysical and spiritual can be accommodated to these same laws. This however comes for demonstration in our psychological Transactions; for it must be known what the soul is, what the spirit, what the body, what the animal spirit, and how one flows into the other; the terms themselves must be explained and the nature of each thing signified by the words be brought out, before we enter upon an exposition of this subject. If the subject is clear and the terms unknown then we speak by mere occult qualities as though speaking Greek to the Latins and Latin to the Greeks. Meanwhile let us agree in this, namely, that memory is a state induced on the organic substances or corticals of the cerebrum wherein the soul actuates its rational mind.*

521. *In order that the causes may be perceived we must add that there is a memory of universals and a memory of particulars. The memory of universals is that which corresponds to our thought, and the memory of particulars that which corresponds to the imagination. The memory of universals is the intrinsic or internal memory of the corticals, while the memory of particulars is the extrinsic memory of the corticals, or their common state. But these statements are still obscure, for the matter is one that cannot be expounded in a few words.*

Thought itself is an active state of the memory of universals, and imagination is an active state of the memory of particulars. They may be conjoined and they may also be separated; for there are those who excell in the memory of universals and consequently in judgment, and there are those who excell in the memory of particulars or in imagination; rarely are the two memories entirely conjoined. But let us come to the causes of loss of memory.

522. *There are many causes; to wit, proximate and remote, and also internal and external. The* PROXIMATE CAUSES *are the red blood and the purer blood. If the red blood penetrates all the way to those passages which lead into the tiny beds of the cortical substances, it not only stops up the pores, impedes the influx and empties the cortex and fibre, but it also moves the cortex from its place and thus takes away its faculty of change of state. Thus, with a deficiency of inflowing spirit, the cortex is unable to run through its states; and even if it does run through them, one cortical gland does not correspond to another, which has been moved from its seat; and thereby is destroyed harmonic variey, mutual respect, and order with its rules. The* REMOTE CAUSES *are those which are the causes of the proximate cause, such as mania and acute fever, besides an infinitude of other ills. For there is no disease invading the cerebrum which is not the cause of some loss of memory. The* INTERNAL CAUSES *are over-intension of the mind upon one subject, and the resulting over-expansion [of the cortical glands] so that they are incapable of springing back; or their over-compression so that they are no longer expansile and versatile; likewise their rigidity, laxity, etc. The* EXTERNAL CAUSES *are the ulceration, wounding, or destruction of the glands; also the pricks of poisons, the biting of sharp-pointed percurrent parts, wounds inflicted on the cranium and on the cerebrum itself, tumors, hydatids, inflammations of the cortex, medullary substance, or meninges, rheumatic obstructions, divers sicknesses of the animus and many other ills. From the symptoms is known the source of the cause, and whether curable, permanent or deadly.*

FANATICAL IMAGINATION.

523. *Loss of memory involves also loss of imagination and thought, for imagination is the active state of the memory of generals and particulars, and thought is the active state of the memory of universals and singulars; thus when the one perishes, necessarily the other also perishes. But there is a fanatical imagination, or an internal sight,—in the daytime almost without any use of the external sight or eye, except a very dull one; this is called* HEMERALOPIA, *and when it occurs at night* NYCTALOPIA.

524. *But before we can know the origin of such violent phantasy, we must first know what imagination is and what thought; also what is the difference between them, and how the one acts into the other. That imagination and thought are in themselves distinct faculties is a fact noticed in brutes; for these enjoy imagination but not rational or intellectual thought. And that they can be separated is a fact noticed in somnambulists, and also in every human subject; for there are subjects who excell in the one and not in the other, and the two faculties rarely exist in like degree in the same person. Imagination belongs to the cerebrum, but thought to the cortical substances of the cerebrum. Thus imagination is an active state of the corticals, that is, of the principal* parts of the cerebrum; that is to say, it consists in the whole cortical gland putting on changes of state generally; for the cerebrum can imagine nothing to itself except by means of its parts which are organic. Thought on the other hand belongs to the parts in the cortical gland; for, in that it is an organ, a little cerebrum, a little sensory, it must consist of parts, namely, of a pure cortex, which is the origin of simple fibres, and is disposed in the utmost order according to the most perfect form of nature. Thus thought is a change of the internal state of the corticals. Consequently, a like state of all the corticals in themselves constitutes the gyre of our reason.*

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*The word is used in its root signification as meaning "beginning" or "originary."

525. *From this description the nature of the state of fanatical imagination is apparent, namely, that the cortical substances of the cerebrum remain rigidly in a state that has been once induced, and do not suffer themselves to be bent therefrom into other states. Therefore they do not dispel, dissipate and remove strange and illy consociated ideas that come to them; but either they absorb these and thereby immensely augment the idea conceived, or they reject them as non-concordant. For in every rational analysis there is a certain form compounded of particular ideas and these again of ideas still more particular; among such ideas there must be a perpetual difference, in order that, taken together, they may constitute a certain rational harmony which is the same as the analysis itself; thus there must assuredly be insinuated relatives more or less opposite. These are not admitted into the sphere of this fanatical imagination. Moreover, if this rigidly permanent state, be enkindled, made active and subtly tremiscent, namely, by some longing or grief, which is ultimately self-augmented, it then refuses all the objects of the sensible things that flow in by way of the external organs, and turns them aside, or else it admits them as exasperants.*

526. *The cause of so dire and dreadful a phantasy is every cause mentioned above as being the cause of mania, phrenitis, and deliriums; thus every cause arising from an immoderate and acute heat of both bloods, from the hardness, unition, or grossness of the parts; from the blocking up of the arteries, corticals or fibres,—unloading into the veins and sinuses of the dura mater being denied them; consequently from the inflammation of the corticals. Likewise from sicknesses of the animus, namely, from grief thereof, sadness, the sudden extinction of hope or a relapse from the highest degree of internal joy and natural light into the lowest, and into gloomy sorrow,—this event resulting especially from an excess of love or of pride. Moreover also from a most intense application and ardor of the mind, and from a confused convolution of ideas, and thus from the precipitation of the mind from a sphere of light into a sphere of shade,—and thus especially in the case of those who ardently desire to contemplate the state of the* *soul after the fate of the body; that is, when intellectual faith studies to attribute the greatest part to itself.*

527. *Moreover the state of the sight itself, that is, of the eye, is also usually perverted, namely, by inflammations, fluxions, contusions, tumors; affecting its tunics, humors, uvea, iris, pupil, retina, optic nerve. Thus images are represented to the animus which induce a state unlike the things themselves; hence likewise come illusions and things imaginary. But so long as the mind is still sane such illusions can easily be dispelled, the fact that they are sports and fallacious and fatuous appearances being well enough perceived. On the other hand, if both sights, the internal and the external, labor under a like sickness or rigidity then the evil is doubled.*

STUPIDITY, FOOLISHNESS.

528. *There are some who live obscurely, almost in the body alone and but little in the mind. Absent-minded,* senseless, heavy, stolid, ever confused, dull, they stick in generals without any particular, in universals without singulars; when things are said to them they perceive sluggishly and no more than half perceive; they take in objects in an indistinct way, and they have not even an inkling of the connections of things and of the superior forms and ideas resulting therefrom; they satisfy their inclinations and indulge their animus without reason; they snore night and day; hence they are obese and are thus subjects as it were midway between subjects of the animal kingdom and subjects of the vegetable. There are some who are born impotent and foolish,—a circumstance usually ascribed to magical art and poisons.*

529. *Their cerebrum is usually watery, pituitous, beset with a sluggish and viscous phlegm, of large size without cultivation, relaxed, loosed from its connections, languid, and thus confused and as it were moss-grown; also deformed, not rounded at the sides, sharp at the sinciput, an effigy of which sharpness frequently shows forth in the forehead and face. The dura mater is flaccid, torpid, not well elastic; the members of the cerebrum are not given their proper place, size and na-*

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*Animus.

tural connection; as is also the case with the cortex in its structure, which in other respects is gross, sluggish, sparse and not entirely, still less, distinctly, formed. The cortical beds are conglutinated and, not being erect, are inattentive, insensible, wavering, somnolent, stuffed, and like sons of a fat Minerva. The cerebellum holds the key of the kingdom, even in the daytime.

530. *The causes are many. The* CONGENITAL *or* HEREDITARY CAUSES *come immediately from the parents by reason of their contrary inclination, or of some affection or imprudence of the gestating mother, or of compression of the head or other injury suffered in the womb. The* CONTINGENT CAUSES *are from chronic diseases, cachexia* of the humors, malignant catarrhs, coldness of the blood, and a congelation as it were of the lymph. The* ACQUIRED CAUSES *are from long continued remission of the mind and dejection of the animus, desires, longings and loves; that is, from privation of the heats of life, and defect of the spirits,—on which account it occurs in the aged; from the giving over to the animus of the government of the mind, and from the giving over to the body of the government of the animus; from indolence, an immoderate use of sleep, gross aliments and drinks; likewise from a confused method used by teachers, undue flogging, etc.*

SOMNAMBULISM.

531. *There are some who at night are aroused as it were from sleep and, being half awake and with eyes and other senses open, move their members and body as though from will, and also talk, sing, nay, walk, go up and down stairs, and, like machines, do with the body alone whatever is to be done; but the rational mind, which is still fast asleep, does not sit at the helm, that is, does not perform its due work unitedly with the body. Thus the external man seems to be awake while all the time the internal is separated or quiescent. Nay, the things done at this time subsequently withdraw themselves into the*

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*Grievous distemper. In its root meaning the word signifies bad habit or disposition, an evil condition.

memory as though they were dreams. The subjects are aroused from this superficial life into internal and genuine human life only by the powerful affecting of one of the senses, by pain, by a fall, or else, at last, spontaneously. Who thence does not conclude that the imagination is one thing and the rational thought another, and that they have their being conjointly and can have it separately?

532. *As concerns the state of the cerebrum of somnambulists it exhibits nothing special wherein it differs from the cerebra of other persons; for somnambulism may happen with anyone, although with some it is a familiar trait. The cerebrum is indeed erected and its folds separated, since the subjects are awakened from sleep. But the inmost cause lies in the corticals themselves. These can indeed be expanded, can engage in work, can change their states and run through them,—but only in a general way; their internal state however lies still fast asleep and incapable of elevating and turning itself. Therefore nothing rational comes forth until those little cerebra are deeply awakened. On this account the cause of somnambulism is to be sought in the internal state of the corticals, and this is not apparent to the most acute eyes, even when furnished with the microscope, except by comparison with the larger cerebrum whereof the cortical substances are patterns.*

533. *But the cause of somnambulism is usually a sleep penetrating all the way to inmosts, the imagination meanwhile remaining strong and the operation of the spirits powerful. The natural constitution is in vain visible in the cerebrum, being inseated in those tiniest cerebra, that is, in the cortical substances. From what is visible we may be allowed to surmise by comparison that the simple fibres of which the whole corpuscle of the cortical gland consists, are obstructed and steeped about as it were by an abundance of the first essence of the blood, which essence so compresses the most simple fibrils, nay, that most simple cortex which is the origin of the fibrils, that the internal state cannot be changed. Thus there is no thought ready at hand, still less any judgment and will such as is called rational. But these points are obscure so long as we* *are ignorant of the form and contexture of the composition of the cortical gland.*

INCUBUS.*

534. *It is called incubus because at night time it appears as though a spectre were incumbent upon the chest, taking away by its pressure, the faculty of respiration. The subject is as though awake but immersed in phantasms; for he seems to himself to will but to be unable to act, so that effect fails endeavor.*

535. *The cerebrum labors from lack of arterial blood, which blood, when attracted from the cavity of the carotid,† does not penetrate all the way to the cortex, but, gliding over the surface of the meninx, falls straightway into the veins and sinuses of the dura mater; thus the vascular substance, which is abundant in the cerebral medulla, is emptied out, and so, being thus extended and stretched, it implicates the fibres; the fourth sinus‡ thus pours out but little blood. Meanwhile the spirit approaches through the vessels emulous of the fibre and flows into the cortex. Thus impotency of action occupies the cerebrum, nay, also impotency of sensation except in an obscure way.*

536. *The cause is usually lying on the back, whence results a derivation of blood into the sinuses of the dura mater,—falciform and lateral,—and of but little blood into the cortical and medullary substances; for these sinuses occupy and engirdle the posterior part of the cerebrum. There is likewise a compression of the larger arteries and veins in the body; thus the lungs, which receive all their blood from the heart and again transmit it, labor under a defect of blood. From these two causes, namely, in the cerebrum and in the body, the respiration is stifled; for the action of the animation of the cerebrum and of the respiration of the lungs is mutual and synchronous. Add to this also grossness of the blood.*

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*Nightmare. The word is derived from the Latin *incubo* "to lie in or upon a thing."

†*i. e.*, its swelling in the cavernous sinus; see 410, note.

‡The Torcular Herophili.

ECSTASY ENERGUMENE.[*]

537. *Ecstasy is taken in various senses. It is as it were a state of body and soul separated, while life still continues; and it is believed that, the soul having meanwhile emigrated from its body, or even if it remains, the bond is broken. Some persons are wont to fall into ecstasy before the death agony. and in respect to the soul, to be elevated outside the world as it were, but to again return into their humble abode or prison house. Some also give the name ecstasy to the half dead state of those who have been shipwrecked, that is, who, after being immersed in the waves, are drawn out therefrom livid in body and face as though dead; but, having vomited the deadly water, and being restored by warmth, return again to their former life. Then also there are persons who, being suffocated and with throat obstructed, are often carried to their funeral couch and their grave, and yet revive. Certain species of animals, such as swallows,*[†] *bears and other species, pass the winter in a kind of death without food or respiration; and there are also cases of men doing the same thing; this life also is called ecstatic. In northern regions certain persons skilled in the art of magic are credited with being able to fall spontaneously into a kind of ecstasy in which they are deprived of the external senses and of all motion, and with being engaged meanwhile in the operations of the soul alone, in order that after resuscitation they may reveal thefts and declare desired secrets. It thus appears that there are many species of ecstasies, and that they agree in this, that the subjects lie as it were extinct in body, but with the interior life still remaining. Nevertheless ecstasy differs from cataphora and coma vigil.*

538. *In persons subject to ecstasy the circulation of the blood seems to have stopped; for the pulse of the arteries is felt nowhere except in the cervical artery, where it is very feeble; the respiration also is gone. Thus there is nothing which shall*

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[*] Demoniacism.

[†] It was supposed by contemporary authors that swallows hibernated, but this is an error.

elevate the muscles and limbs, either on the part of the blood or on the part of the lungs,—for both concur in all actions, especially the voluntary. The blood does not run through its aorta, that is, through the common trunk of all the arteries of the body; but that which enters the right auricle of the heart is carried off through the foramen ovale (which in these subjects should be open) or else through the coronary vessels, into the left heart, and from here it is taken up through the ascending trunk of the aorta and through the vertebral artery, and perhaps also through the carotid, toward the cerebellum and cerebrum; it afterwards returns by the vertebral vein, which issues from the cranium, and by the spinal veins, which run through the posterior region of the long spinal shaft, and from there it flows off into the vena azygos and for a short space into the inferior vena cava, and thence back again into the right auricle of the heart. Such seems to be the circulation of their blood. As regards the cerebrum, it is still vivified by this slight amount of blood and at the same time by the spirit flowing in through the vessels emulous of the fibre; thus the cortical substances, and at the same time the fibres, draw a feeble breath; and so long as this continues hope of life remains in the cold body. Therefore for the leading of an ecstatic life a peculiar disposition is required,—a fact which is also known from the inspection of corpses, and is evidenced in the sea-tortoise, ducks, and other amphibians; namely, in their heart and cerebrum and in the connection between the two, which contributes the largest share to their entering into and continuing such a life.*

539. *The causes are many, to wit, as was said, suffocation of the throat, trachea, and bronchia by angina;† of the lungs and stomach by the water of shipwreck, and by air; and, in*

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*Apparently a slip for *superior*.

†Angina, from a root meaning *to straiten, narrow,* was used by contemporaneous medical writers to signify the inhibiting of deglutition or respiration, or of both, caused by a number of diseases, such as quinsy, bronchitis, sore throat, various inflammations, etc. (Boerhaave, *Aphorisms*, 783.)

persons near the last agony, by the eruption of the blood from the arteries into the veins, together with a deficiency of the animal spirit. Nor would it be entirely contrary to reason to add that there are also some who are able to throw themselves into ecstasy by natural means, whence comes belief in magic.

CANINE RABIES, HYDROPHOBIA.

540. *Persons bitten by mad dogs are sometimes carried off by alternations into a like rabies, the nature of their blood or the inclination of their animus conspiring to this effect more or less vehemently or mildly. The disease is a species of delirium and wandering mania which in certain subjects so inspires the life and blood, that they burn to lay hands on whomsoever they may meet, and this even after the lapse of many years. It is said that the same symptoms are wont to result from the bite of other animals, nay, from the rage of excited men.*

541. *To give the inmost causes of such phenomena is not in my power; for we ought to know not only the genuine nature and composition of the blood, but also the nature and composition of poisons and of their varieties. There are poisons both of the mineral kingdom and of the vegetable, and likewise of the animal kingdom; and of each of these there are many genera and an infinitude of species. Poisons are such things as do not concord with our red blood and with our purer blood or animal spirit. Such non-concordant things are all those that, if compounded, cannot be dissolved, and if of a simpler nature, cannot be united, and which yet penetrate the vessels and fibres. They cannot be dissolved if they are too hard and compact; and they cannot be united if they are not yielding, concave, and capable of being applied to the convexity of the blood globules, as for instance, all saline, sulphurous and urinous parts both primitive and derivative. Poisons, if they be sharp-pointed, cannot but pierce, tear, and disrupt the blood globules set in the gyre of the circulation; and likewise make them cold and conglutinated, impeding both solution and composition; and thus destroy the entire mass,* *and at the same time, the capillary arteries and the fibres. There are also compound poisons which are at first innocuous, but presently, when they break out of their congeries or mass, go off into poisons exceedingly subtle, and thus everywhere infest the blood stream; for unless they are rejected the necessary result will be that a small supply of them will irritate the entire stream of the blood in its course through the vessels and fibres, since they invade the blood globules one after another. But the real nature of poisons is known only from their effect; namely, whether they thicken the blood into a cold and glutinous mass; or destroy the regular modes of the circulation; or tear apart the globules themselves; or lie fixed in the vessels, fibres, and in the cortex itself whence arises dementia and fury.*

542. *But as regards the poisons* (aconita) *of mad or Cerberian dogs, we may be allowed to augur that they are minute frothy or salivary globules,—oval as it were and furnished with a somewhat rough tunic,—in which lies hidden a mixture of such poisons. If these oviform vesicles are carried into the fleshy structure by a bite, they remain entire for a long time; nor do they mingle in with the blood unless dissolved by heat and delay, when they produce terrible slaughter, destroying, that is to say, one globule after another, or else a number at the same time. This may be the cause of the rabies returning at intervals. As to the more proximate cause [of rabies] we may not guess.*

TARENTISM, ST. VITUS' OR ST. GUY'S DANCE.

543. *Tarentism arises from the bite of the tarantula. The patients lie sometimes with members benumbed and, wonderful to relate, certain melodies excite them to dancing. Demented, they leap like pantomimes,* and toss their limbs; nor do they come to, or are healed, except by a profuse emission of sweat. Not unlike is the case in St. Vitus' dance, for in this disease the arms and body of the sick person are contorted in a remarkable manner, and a similar kind of dance returns at set intervals.*

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*Actors who express their art by actions and mimicry without speech.

544. *It is a well known fact that virus brought in by a bite is the cause of this phenomenon, but the nature of the virus is not easily divined; for there are various genera of poisons and innumerable species. Who knows the forms of each genus or species? their disagreements with the blood and other humors purer and grosser than the blood, and with the vessels and fibres? And who knows the analogy of the stringent and titillating prickles? We are ignorant of the presence of such things in the aliments that prick or soothe the papillæ of the tongue, whence comes taste; or in the streaming exhalations that prick or soothe the glands of the membrane of the nostrils, whence comes smell; what then of those things that are taken in by no sensation! For whatever most minutely touches the organs of the senses, both of the sight and hearing and of the taste and smell, this same, and also its several differences, produces an affection all the way to the cortex or common sensory. On this latter it induces a similar state; for without variation of state the cortex would be inapt and impotent for sensation. Therefore these glands, being so many little internal sensories, are affected, that is, undergo suitable changes of state, according to every cause and variety of the forces and forms that flow in.* See above, n. 479. *As is the state of the sensation or perception such becomes the state of the thought, and such also the state of the will; for sensation or perception, thought, and will, are in one series, since in the mind they mutually follow each other. Now if forms flowing in from the organs of the senses change so suddenly the state of the cortex, what then do not the analogous similar forms in the fibres and in the cortex itself accomplish; that is to say, the forms analogous to those in which is the state of the cortex when taking in those modulations with the ear and in suitable accordance therewith leading the dance or tossing the limbs in leaping. As soon as the sensory, now dull and sluggish, is excited into this state, a like and analogous active force is also excited, just as one string is excited by another and concordant string. Nay, by certain harmonies, we ourselves are sometimes moved to dancing. I have seen a hare taking in melodies* *with pricked up ears, and which always leaped up at one certain melody. But this by the way. It is inevitable that the poisoned corpuscles of the tarantula stick in the fibres or else beset the cortex; which latter cannot put forth their forces until the sensory is excited into a corresponding and harmonious state; then, at the least such state, the poisons cause the cortex, thus excited, to fluctuate and leap in various ways; hence the gesticulation and the tossing of the members as though dancing. The effect teaches this with all certainty. Furthermore, these poisons are suitable to the blood of the tarantula but are by no means suitable to human blood; for persons who have been bitten by tarantulas or scorpions are cured by oil mingled with their blood; for the oil absorbs things homogeneous, and inmostly stores away such as can never be united with the blood of another.*

CHAPTER XII.

VERTIGO, SCOTOMIA, LIPOTHYMIA.

545. Vertigo takes its name from *vertere* (to turn). It is called *simple vertigo* or *dinos** when the objects before the eyes turn round and rotate; but this clears away in a moment. It is called *vertigo tenebrosa* when many colors come before the eyes and the sight verges to darkness; such vertigo is also called *scotomia.*† In like ratio with the sight and sensation, is weakened also the will and the force of the muscles; the languidness thence resulting is called *lipothymia.* In these cases it is not the eye that is darkened, but the common sensory; thus neither is it the muscle that grows languid, but the common motory. The sensory and motory organs of the body are only instrumental causes, or instruments whereby the cerebrum sees and acts. Anæsthesia is the loss of the faculty of perceiving the actions of objects upon the organs of the senses.

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*The Greek word for vertigo, or giddiness.

†From the Greek word *Scotos* (darkness.)

546. When this vertiginous darkness invades the cerebrum, the arterioles grow pale; together with the cortex of the fibre, they close themselves up; the cerebrum does not reciprocate its breathings and live,—for the corporeal life of the cerebrum consists in its animatory motion; hence arises vertigo. In simple vertigo however the cerebrum soon raises itself and recovers its spirits, while in vertigo tenebrosa or scotomia it is quiescent for a longer time. The like is the case with the muscles which depend on the will of the cerebrum. For as is the state of the cortex such is the state of the senses, the will, and the actions, since in them the fibre is everything, and the cortex is present in every fibre. There is also a species of vertigo when the cerebrum disposes itself to receive only the purer blood and holds the red blood off at a distance,—the latter then pouring immediately into the veins through the larger commissary vessels. In this state the cortex grows pale, the pia meninx is inflamed, and the sinuses of the dura mater are stuffed with cruor; and this is the more the case according as the patient lies with head thrown back; therefore a forward and lateral position is demanded, otherwise he will easily fall into a deadly swoon.

547. Every cause of the diminution, shutting off, and defect of the spirits is a cause of some kind of vertigo. The spirits are what course through the cortex and fibre and, by the mediation of the cortex, make a perennial circle from fibres to blood and from blood to fibre; there are also vessels emulous of the fibre, as it were venous or return fibres, which convey to the cortex the purest serum. The causes of defect of the spirits belong to the body and to the cerebrum. *Causes in the body* are almost all those that are the causes of the hypochondriac disease [*supra,* n. 493, 494], namely, pain in the stomach and intestines, and the emptiness, nay, and also the excessive fullness, of these parts, which thus compress or stop up the mesenteric and thoracic ducts. Consequently it is caused by ulcers, abscesses, worms, coarse and irritating foods, poisons; for at contacts like these the stomach, together with its vessels and circulatory pipes, is constricted. The constriction, blocking up and occlusion of the lymphatic passages in the pancreas and spleen, and, with women, in the womb, produces the same effect; for the highly pure humor of the lymphatic vessels, when it is instilled into the veins of the body, is immediately withdrawn towards the cerebrum, since it is extremely light, serves the better blood as a vehicle, and carries on its own circulation. There is a like spring ot perennial lymph in the cerebrum, where it drips out between the arachnoid tunic and the pia meninx, between the cortical windings and folds, and between the medullary plexuses and layers; and therefore it has been chemically proved that the lymph of the cerebrum and the lymph of the thoracic duct are of the same nature. When the cerebrum is despoiled of this lymph the cortex straitway becomes faint and is rendered incapable of action. Such an atrophy and drying out of the cerebrum is a cause of vertigo; for when the blood is too dry it cannot approach the cortex. Vertigo and languidness or lipothymia and swoon arises also from an excessive emission of the blood by venesection, hemorrhage of the nostrils, or wounds; also from excessive outpouring of the sweat as in baths; from an excessive exercise of venery; likewise also from sudden occlusion of the least pores of the cuticle, the inhibition of the Sanctorian perspiration, cold, etc. *Causes in the cerebrum* are almost as many as are the sicknesses of the animus which suddenly constrict the cerebrum and cortex, and expel the mind; such for instance as grief, sadness, fear; also, in certain subjects, anger; consequently all circumstances that produce such changes; likewise over-intension of the mind, especially when the sickness of the animus penetrates deeply into the sphere of the operations of the mind. Thus the cortex is closed and, with the compression of the cerebrum, the way of transit is interrupted; nor does the cerebrum revive except after some delay and at the urging of the great need of the body. The more prone the animus is to changes, and the more sensitive the mind, so that the change deeply penetrates the mind itself, the greater is the proclivity to vertigo and swoons. Therefore this condition obtains more frequently in the feminine sex than in the masculine; for men fall into swoons for the most part from causes in the body, while women, being more tender and sensitive, fall into swoons from all the causes in the body and in the animus, and from almost every sickness and grief; to these causes is also added a cause arising from hysterical and other diseases of the womb. With some this evil condition exists as an inheritance, with others as an acquisition; for when swooning returns too frequently, the cerebrum easily becomes accustomed to it, and at last it falls and faints away at a very slight stimulating cause.

SWOON, SYNCOPE, ASPHYXIA.

548. *Swoon* is also called *falling vertigo;* it is generally preceded by vertigo tenebrosa. *Syncope* is the name given to a sudden swoon without motion or sensation, the patient being left with a very feeble pulse. *Asphyxia* is like syncope, but with the loss of the pulse.

549. Simple vertigo is the first degree of swoon, vertigo tenebrosa is the second, syncope the third, asphyxia the fourth, and death the last. The state of the cerebrum of a patient in swoon is like the state of the vertiginous cerebrum, except that there is more or less defect of the spirits, and a longer-enduring or more compressed occlusion of the corticals or of the fibres; both the quantity and the quality are known from the effect. When the cerebellum is deprived of its spirits, then, as in the case of asphyxia, the pulse of the heart and arteries also ceases. It is therefore superfluous to enumerate causes since they are the same as those mentioned above in treating of vertigo.*

550. The proximate cause of the motion of the heart is the venous blood flowing into the right auricle of the heart. A more remote cause is the blood which comes down through the jugular veins from the cerebrum as from some living fountain, and which ever excites the circle of blood to a con-

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*The chapter on vertigo (n. 545 *seq.*) mentions only the cerebrum; but by *cerebrum* is sometimes meant the whole brain.

tinuation [of its course].* A cause still more remote is the spirit of the fibres, or the fibres that flow into the præcordia,† —fibres which belong to the cerebellum alone. Therefore if there be a cessation of either the first, second, or third cause of the motion of the heart, straightway the pulse also ceases; but of these points we have treated in Transaction I in the chapter on the Motion of the Adult Heart [n. 468 *seq.;* see particularly n. 512-537, 555-557, 558-561, 578]. Consequently any cause giving rise to palpitation of the heart may also be a cause of swoon.

551. On the other hand the respiration of the lungs arises proximately from the incumbent and inflowing air according to its weight; the lungs themselves expel this air from their vesicles, being aided by the joint effort of the ribs and muscles which compress them. More remotely, however, the respiration of the lungs arises from the cerebrum, cerebellum and medulla spinalis; for the fibres belonging to these three flow into the costal and other muscles of the thorax and abdomen. The causes of the cessation of the respiration and pulsations in swoon are therefore apparent.

ATAXIA.

552. It remains to be added that in all the diseases of the head enumerated above, that is to say, in swoons, vertigo, tarentism, mania, deliriums, apoplexy, epilepsy, etc., there is an irregular flow of the spirits, or *ataxia.* Ataxia is present not only in all diseases of the body but also in the sicknesses of the animus, nay, even in the desires of the mind; in a word, in every change of the state of the corticals,—as is noticed especially from the unevenness of the respiration; but only the ultimate effect is called a disease. It is thus apparent how many are the diseases and how many the dangers into which the cerebrum alone and its will and sensation, or rather its inconstancies and changes, lead us. The universal cause of diseases, nay, of unhappiness and death, is that our will strives against the order of nature and opposes itself thereto.

**qui circulum sanguinis toties ad continuationem excitat,*—literally "which as often [as it comes down] excites the blood to a continuation.

†The thoracic viscera.

CHAPTER XIII.

CATARRH AND RHEUMATISM.

553. *Catarrh* is a disease which, for the most part, takes its origin in the cerebrum; for the fact of there being a collection and inundation of some kind of enclosed humor, sluggish, stagnant, heavy, changing place and as it were worming about,—especally in the sinciput, and also elsewhere between the ethmoidal crest and the lateral processes of the dura mater which distinguish the cerebrum from the cerebellum,—is manifest to the sensation. Sometimes a dull pain is noticed, and also a sharp pain; this is followed by loss of sensation, especially of taste and smell, dullness, languidness, a doubting and hesitant determination of the will and actions, loss of memory, and many other effects which result from the blunting and dulling of the sharpness of the internal senses. After a time the pituitous matter usually begins to thin out and disperse, and to be eliminated to the outside by a number of paths according to the leading of the nerves. It is then generally called simple *rheumatism.*

554. Catarrh, properly speaking, is a collection, between the cerebral meninges,—dura and pia,—of a pituitous and mucous ichor secreted from the arteries of the dura meninx if not from those also of the pia. It is believed also to be present between the cortical windings or under the pia meninx, and moreover in the interstices of the medullary substance. But catarrhal lymph does not penetrate so far; for that which is collected between the meninges is prevented from thus penetrating by the obstruction of the arachnoid tunic, and also by the pia meninx; such lymph, moreover, is too sluggish, being as it were a mucous. Meanwhile, the dura mater which is an elastic and reactive suspensory, is continually raised up and relaxed as often as the cerebrum tumesces and detumesces. Thus the collected ichor is pressed and driven about, and, in fact, by the leading of the fabric, towards the cribriform plate; for every motion of the cerebrum tends and determines thither as to its fulcrum. Therefore the ichorous collections seek this place as their asylum,—which is the reason why they are wont to be constantly determined into the cavities of the nostrils. To prevent the stopping up of this pathway sneezing is usually excited, which is the forerunner of catarrh; for thus the wandering liquids are dispersed and the ways to the exits constructed by nature made plane. It is a known fact that innumerable fibrils of the olfactory nerve, surrounded by the pia meninx and also by the dura, pass through the foramina of the cribriform plate, and insinuate themselves into the cavities of the nostrils where they are disseminated throughout the mucous membrane. Between these two meninges little interstices continually open out into the foramina. It is true that in collapsed and dead brains these interstices are found stopped up, and indeed so stopped up that, according to the testimony of Vieussens, not a drop of injection could be forced through them.* But such is not the case in living and wakeful brains. When all the parts are expanded, erect and distinct; when, at the same time, they are in perennial reciprocal motion, and the very fibrils alternately compress themselves; then necessarily there must be open passage. Not only does experience confirm this, but it demonstrates it before the senses. Who does not sensate the pituitous collection from its very weight? from the pressure and pain? and from the actual flow through the nostrils and throat? Add to this that there is no path of exoneration other than into the nostrils or into the nerves leading from the cerebrum. The existence of both paths is also

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*Vieussens maintained that in the natural state no pituitous or mucous humor is collected between the dura and pia meninx. Among other arguments he adduces an experiment in which he injected some warm fluid between the meninges. Though the dura was swollen by the injection, yet the whole of the liquor was retained between the two meninges although provision had been made for its escape through an incision in the dura mater above a ligature placed on the medulla spinalis. From this Vieussens argued that there could be no exoneration of any pituitous humor from the intermeningeal spaces, and consequently no collection of such humor in those spaces. (*De Cerebro,* Cap. XVI *ad. fin.*)

proved by experience. The cranium itself is everywhere impervious, nor is there any opening except for the arteries, veins and nerves. The same is the case also with the dura mater. Nor are there found any veins to absorb this humor, except such as are thrown towards the sinuses of the dura mater. In this catarrhal state of the cerebrum the coarse meninx is for the most part slightly relaxed, and sometimes also thickened; and, by reason of the interjacent moisture, it presses upon the subjacent arachnoid tunic and pia mater with their arteries. Thus, with the cerebrum carrying on its diastoles and systoles, the liquor is certainly driven around, and this, naturally, as was said, towards the cribriform plate, or else also towards the other corners of the cranium where the nerves have their exit, and where the fascicles of fibres unite together under a common sheath, namely, the dura mater. Thus this dissolved mucosity may also be derived towards the nerves,—but this path is a deviation. Consequently, according as the condition and mind (*animus*) of the cerebrum carries this humor, so it is determined either to the motor nerves of the eye, or also to the third, fourth, and fifth pair of the head,* or to the auditory nerves, or the gustatory; thus to the ears, tongue, gums, cheek-bones, face; nay, also to the shoulders, arms, hips, and other parts of the thorax or abdomen; that is to say, to wherever the nearest or more open path has led it. It is likewise determined towards the medulla spinalis; for at the posterior part of the great foramen of the occiput, a passage opens between the dura and pia mater and afterwards, according to the connection of the same causes, between the fascicles of fibres going out from the spine; consequently a similar wave is derived through the nerves into every quarter and part of the body. If it passes through the great intercostal nerve immediately into the texture of the lungs it gives rise to *suffocating catarrh,** which is also called *cardiac syncope;* for the epiglottis and trachea are closed. But if it goes to the costal and other thoracic muscles the inspiration labors,—as in *paraphrenitis* [cf. n. 516]. If it goes towards the loins it is called *rheumatic lumbago;* if to the hip, *coxic*† or *sciatic rheumatism.* The difficulty of moving oneself is called the *sciatic pain,* which is a kind of formication‡ pricking the senses. Thus, according to the parts to which this lymph is determined, the disease receives its name, and becomes more or less dangerous. The inundation especially reaches the glands, such as the parotid, the throat-glands and others; also the ganglia, wherein a number of nerves come together; hence results hoarseness of the voice or *aphonia.*|| Nay, when such an ichor is determined in any one direction two or three times, it afterwards presses along that path as though the same had been made open and plane. Especially is it important to observe the quality and quantity of the ichor; also the sensibility of the part into which it flows, whether, for instance, the fibres flowing into the membranes and muscles be fibres of the cerebrum or fibres of the cerebellum. With the help of anatomy this is ascertained with considerable accuracy from the seat, quality, and quantity of the disease, pain, and danger.

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*These are, the oculomotor (3d), the trochlear or patheticus (4th), and the trigeminal (5th). The first two are motor nerves to the muscles of the eye, and the third includes the motor nerves of the jaws and the facial nerves of common sensation.

555. The causes of the secretions and of the catarrhal flow between the meninges of the cerebrum are many in number. The proximate cause is from the arteries of the dura mater, and perhaps also from its other filaments; for when compressed, the dura mater continually distills a mucous. It does not seem probable that the secretion comes from the arteries of the pia meninx; for these creep in the duplicature of the meninx and their sweat is at once led off to between the folds of the cerebrum. The causes of the secretions, how-

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*Defined by Blancart as "the highest degree of dyspnœa, or a sudden intercepting of the respiration accompanied with redness of the face and stertor."

†From the Latin *coxa,* a hip.

‡*Formicatio,* from *formica,* an ant. The word is used to indicate a pain or irritation such as would be caused by ants creeping over the affected part.

||Complete loss of voice.

ever, are obstructions and inflammations; to wit: *In the body,* obstructions of the accustomed evacuations, as through the bowels, the womb, sweating, effluvia, hemorrhoids; for the fact of the retention causes that the serosities must be unloaded somewhere. But the causes of the obstructions are many in number, being especially the temperament, the animus, changes of the air, of cold and heat, of food and drink; especially when such changes occur in those members that are approached by many fibres of the cerebrum, such as the soles of the feet and the muscles of the occiput. Also *in the cranium itself,* for cold also penetrates the pores and sutures of the cranium and closes the communicating passages and the veins themselves,—a large number of which pass out through the sutures and in other places; thus the paths of exoneration for the vessels and threads of the dura mater are entirely stopped up. Causes are also met with *in the cerebrum,* as, for instance, too great compression of the arteries of the meninx; denial to them of exoneration through the nostrils; excessive somnolence and carelessness;* excessive remission of the animus and mind and also excessive intension; for remission results in the cruder parts being drawn up towards the cerebrum, and intension, in the exits through the sutures of the cranium and into the veins being closed.

556. There are many kinds of catarrhs, for they are as many as are the determinations into glands, muscles, sensory organs, members and viscera of the body; and especially, as are the kinds of serosity in the blood. The serum draws its nature from ordinary food, being that which is taken in by the mouth and carried into the stomach; from atmospheric food which is drawn in by the respiration and which passes into the veins by means of the cuticles; and from a still purer food which transpires through the most subtle pores. The red blood and the purer blood is impregnated by all these foods. There are foods, exhalations and vapors which are less or more suitable to the blood and thus dangerous and deadly. When foods of this kind defile the serum, then, by the striving and urging of the whole brain and body, they are re-

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******Incuria,* excessive indifference as to the affairs of life.**

jected and expelled as though enemies. Hence a conflict arises, and there is a struggle for the arena, vessel or blood. From this cause also a secretion arises, and thence a more malignant catarrh or rheumatism, which, when it breaks out, is more painful giving rise to excruciating pains and tormina.* This is the reason why the catarrh of one region is more dangerous than that of another; nay, it is often the case that one kind of catarrh prevails during a set time and attacks those with whose blood it disagrees; for exhalations,—some exceedingly subtle,—will arise from a certain part of the earth's bosom, from the ocean, from clouds, from pestiferous diseases, or from change of seasons; and these infect the air or ether, and thus the atmospheric food just mentioned.

RHEUMATISM.

557. The name rheumatism is also given to a disease that severely attacks the membranes, tendons and joints of the bones; for it consists of a collection of an acrid lymph mingled with heterogenous substances and not suitable to the fibres of the membrane, tendon or joint. The special seats of invasion are the popliteal spaces, the knees, loins and other ginglymoid joints,† nay, and also the softer substances; hence arise tumors, redness, indurations, frictions as when axles and wheels creak from not being greased with the proper oil or from being soaked with some other fluid; hence difficulty in bending the joints, excruciating pain, and many other symptoms,—all of which spring not from the brain but from some other source. In the whole body there exists no joint, socket, symphysis, periosteum, or tendon, that does not demand its own kind of humor; for in each case there are glands near by, which prepare and proffer it. If such humor be either defiled or illegitimate it sticks, ulcerates the fibres and deprives the member of the faculty of action; hence come painful results and so forth.

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*The word is technically used to describe pains resulting from contraction, such as the pains before and after labor, of dysentery, colic, etc.

†A ginglymoid joint or articulation is one that permits motion on a single axis approximately transerse to the long axis of the bone. The knee joint is an example.

558. The usual cause is food, taken in through the mouth or admitted through the pores, that is hostile to the blood; consequently poisons and malign conditions of the air; the inhibition of the perspiration, circulation, or evacuation; especially if the food is imbibed with open pores, as in heat, and then retained by reason of the pores being suddenly closed, as in cold,—in which case it suddenly makes an attack as it were, and widely scatters its infections. Causes of this atrocious disease are also the congenital beginnings of diseases, which, if they do not break out openly, inaugurate the disease with some fever and a slow inflammation; intermittent fever cured before its time; high fever not thoroughly wiped out; the venereal disease not yet come forth; unfermented wines, certain kinds of drugs, and infinite other things. But if a stagnant lymph of this kind turns to pus it then corrodes and lacerates the bony matter, periostea and tendons and, consuming them, causes the most atrocious pain, as in arthritis. Ordinary rheumatism, however, is that disease which takes its origin from the catarrh described above, that is, from a lymph collected between the meninges of the cerebrum.

CHAPTER XIV.

CEPHALALGIA, CEPHALEA, MIGRANIA, OVUM, CLAVUS.

559. Headache is either dull or acute; sometimes an agitation and a kind of palpitation is noticed. Thus headache varies according to its causes. When it affects the whole head it is called ***cephalalgia,*** and, if long enduring, ***cephalea;*** if it affects only half the head it is called ***migrania,*** if only some portion, ***ovum,*** and if only a minute part, ***clavus.***

560. Either the whole cerebrum is affected with cephalalgia, or one of its hemispheres, or one convolution, or some special cortical bed; for the cerebrum is as it were articulated so that one portion may be sick while the other parts remain whole. The seat of the ill, according to its causes, is either in the cranium, or in the dura or pia mater, or in the cortical substance itself, or in the medullary substance; as for instance, when a contused or fractured cranium presses upon the dura mater; when the cavities of the cranium are obliterated and the diploe* is forced out; if the dura mater is anywhere torn away from the bony wall of its cranium,—for the dura mater is attached to the cranium at various points as though by bonds; if the vessels penetrating into the cranium and its sutures, together with the other threads, be too stretched, relaxed, twisted together, ruptured, so that passage through them is denied; if an ichor be collected between the cranium and the mater whence result pittings and cavities; if there be an abundance of humor between the meninges, or between the windings and folds of the cortical substance; between the lamellæ and plexuses of the medullary substance; if the humor in the ventricles be stagnant from the occlusion of its exits, of which latter there are many, to wit, a separate one for each kind of humor,—for there are as many paths of exoneration as there are species of liquor; moreover, if cruor be crammed in the arteries, veins or sinuses and thus the cerebrum be somewhere inflamed,—for its health requires a moderate tempering of cold and heat. On this account *cephalalgia* is distinguished into *hot* and *cold*; and by some into *scorbutic, bilious,* and *pituitous.* In addition there is also *habitual* or *congenital* cephalalgia, not to mention cephalalgia arising from some enclosed matter that is purulent or stale; from scirrhus growths; from hydatids; from the erosion of the parts. Moreover in the medullary part of the brain there are everywhere found receptacles or asylums of the blood and if these are obstructed this also causes the cerebrum to ache. In addition, there are the larger and lesser plexuses, and the various interstices between the layers of fibres; if these coalesce, dry up, expand, or become flaccid, they are disturbed from their natural position; thus headache arises from atrophy, atony, or ataxia; likewise if turgescence occurs in the glands that are interwoven [with the medullary substance] in order to restore the tension. There is nothing more sensitive than the cerebrum,—but thus, there is nothing more distinct; hence in such distinctions lies common sensation, grievous sensation, cephalalgia, and pain.*

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*The cellular structure between the inner and outer bony plates of the cranium.

561. The several diseases of the head are usually preceded by a certain symptomatic pain, as in the case of apoplexy, epilepsy, hydrocephalus, catarrh, fever, and so forth. But ordinary cephalalgia usually arises from all causes that induce a change of state upon the cerebrum, inhibit the alternations of its animation, compress the whole or a part, and that irritate and prick the sensitive threads of the meninges and of the cortical and medullary substance. The cerebrum is wont to be vehemently straitened, carried away, and pained by malignant fumes and stenches, by foul vapors, and still more by pestilential contagions and poisons. For when these attack the blood and humors, including the purer humors, the cerebrum strives with all its breath and forces to expel them, and restore itself to its own natural state; and as long as this endeavor continues it creates a pain frequently of an atrocious character, and this with increase as it carries itself over its balance and limit. The effect of foul odors is taught by experience. They affect the cerebrum according to the whole nature of their action. There are some that soothe and put to sleep; some that convulse the whole cerebrum and excite to sneezing; some that produce

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***Inde communis sensus et gravis et cephalalgia dolorque talibus*. Of the word *dolorque*, Dr. Wilkinson, the Latin editor, writes that he so reads the word "more by using guesswork than by attaining certainty." It "is written in a most difficult style, and the sense throws little light upon the matter." We may add that in the chapter on cephalalgia at the end of the MS work on the Diseases of the Brain (*Photo. MSS*, vol. V, i, p. 625) there is a passage which seems to elucidate the matter. Translated, the passage reads: "There is nothing more sensitive than the cerebrum; but its sensibilities or the degrees thereof are like the degrees of the compositions. It is apparent from reason that the pain of headache is not a distinct affection of the single parts deeply subdivided, but of many parts together, that is, of compounds; and therefore an obscure or obtuse affection is merely their extrinsic compression, divarication, concussion, inharmonious vibration."

disturbance, and, bringing horror to the fibres, bring also discord as it were; for the fibres of the olfactory nerves communicate with all the fibres of the cerebrum. But to resume. The causes of cephalalgia are also varied according to temperaments. In the full-blooded and plethoric the pain is usually excited by inflammation; in the phlegmatic by drying up; in the choleric by privation of the stimulating parts and thus from lack of a mildish bile; so also in the other cases.

CHAPTER XV.

HYDROPS, HYDROCELE, HYDROCEPHALUS, ASCITES, TYMPHANITIS, LEUCOPHLEGMATIA, ANASARCA, HYPOSARCA.*

(Here the MS. ends.)

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*Hydrops or dropsy is the generic term; the other terms indicate the seat of the dropsy, namely, dropsy of the scrotum or testicles; of the brain; of the abdomen, etc.; of the same when distended by air; milk leg; dropsy of the whole flesh; and of the same when the humor is specially viscid.

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INDEX OF SUBJECTS.

The endeavor of the compiler has been to make an index that will be to some extent also a digest. For this purpose many subjects which would ordinarily have separate entries, are grouped together under one leading subject. Thus *affections, memory, thought, perception, mind, animus, soul*, etc., are all entered under *Psychology* where they are in classified order, the various divisions being distinguished by black type. So *animal* spirit is put under *Blood; cerebrum* and the parts of the cerebrum, *dura mater, arachnoid, cerebellum,* under *Brain; blood-vessel, artery, vein, medullary fibre* under *Fibre;* the various diseases under *Diseases*. However, many cross references—indicated by italics—are given as an aid to the student.

The following abbreviations are used:

A.	Anatomists.	Cort. gl.	Cortical gland.	Imag.	Imagination.
An. Sp.	Animal spirit.	def.	Defined.	Med.	Medulla-ary.
c.	Cause.	Dis.	Disease.	Melan.	Melancholy
cel.	Celestial.	dist.	Distinguished.	orig.	Origin.
cer.	Cerebrum.	Fib.	Fibre.	sh.	Shown.
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*Many affections called by our author D's are generally supposed to be normal human affections, for example, hatred, avarice, etc. We have, therefore, listed these under *Psychology* (affections of mind and animus), and have confined the present list to what are medically regarded as diseases.

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p. 3, l. 7, *for* cortical *read* cortical [n. 22].
p. 5, l. 3, *for* see *read* see [n. 57].
n. 60, l. 9, *for* ures *read* ures [n. 17].
p. 6, l. 17, *for* cf *read* cf [nos. 19, 20].
p. 11, l. 5, *for* (*De* *read* [n. 7]. (*De*.
p. 14. l. 3, *for* substance *read* substances.
n. 32, l. 7, *for* Fornix *read* Fornix [n. 17].
p. 91, l. 20, *for* 47 *read* 47 [48].
n. 94, l. 8, *for* semicircular *read* medullary.*
p. 40, l. 10, *for* cranies *read* crannies.
n. 124a, *fn* for *plexuses* read *plexuses; whence arises a structure, loose, spongy, pervious to lymphs, bibulous, soft, capable of expansion, free to act, and suitable for building up the nerves.*
p. 53, l. 30, *for* (n. 57 *read* ([nos. 54-5].
p. 53, l. 36, *for* see *read* see n. 55 and.
p. 54, l. 9, *for* 45, 57 *read* 46, 52-55.
p. 54, l. 10, *for* 91 *read* 92.
p. 60, l. 23, *for* dark— *read* brown—.
p. 67, l. 3, *for* Functions *read* Function.
n. 137, l. 14, *for* to *read* from.
p. 76, l. 24, *for* adhesions *read* adhesion.
p. 78, l. 22, *for* sensation *read* sensations.
p. 78, l. 24, *for* by constriction *read* and constricted.
n. 143, l. 4, *for* force, light *read* force.
p. 83, l. 22, *for* un- *read* in-.
p. 96, l. 10, *for* disappear *read* disappear [n. 6].
p. 96, l. 20, *for* Brain *read* Brains.
p. 169, l. 4, *for* cerebrum *read* cerebrum [nos. 36-38.]
p. 173, l. 6, *for* 37 *read* 36, 37.
p. 180, l. 23, *for* medulla *read* medullas.
p. 187, l. 10, *for* 117 *read* 115.
p. 114, l. 2, *for* thereof in *read* in.
p. 119, l. 22, *for* nous; and he states that it gives *read* nous [n. 22]; and it is said to give.
p. 119, l. 23, *for* 22 *read* 4.
p. 120, l. 1, *for* 49 *read* 49-50.
p. 121, l. 26, *for* 22 *read* 22, 24.
p. 122, l. 19, *for* up *read* of.
p. 124, l. 12, *for* spider *read* frog.
p. 125, l. 9, *for* [*Arc.* *read* [n. 24, *Arc.*
n. 213, l. 4, *for* 46, *read* 46, 47.
p. 139, l. 14, *for* 16, *read* 18.
p. 139, l. 15, *for* fig. 2 *read* fig. 2 [n. 29].
n. 237, l. 25, *for* tendinous *read* finer.*
n. 250, l. 10, *for* substance *read* substances.
n. 254, l. 3, *for* essece *read* essence.
p. 168, l. 16, *for* 34 *read* 33.
p. 169, l. 20, *for* expansions and contractions *read* contractions and extensions.*
p. 187, l. 1. *for* o *read* of.
p. 195, l. 6, The footnote is on p. 194.
p. 198, l. 15, *for* Aeg. *read* Aegypt.
p. 199, l. 5-6, should be transposed.
p. 203, l. 14, omit quotation mark.
p. 220, footnote. The title cited was supplied by Dr. R. L. Tafel, the MS. having no title.
n. 319, l. 26, *for* ther *read* their.
p. 241, l. 28, *for* [Opera *read* [n. 9. Opera.
p. 250, l. 2-3, *for* a general [centre] *read* the commonwealth.
n. 346, l. 12, *for* 327 *read* 329.
n. 355, l. 9, *for* meninx *read* meninx [nos. 9-10].
n. 355, l. 15, *for* 335a *read* 334a.
p. 274, l. 24, *for* membranes* *read* members *and omit footnote.*
n. 421 seq. In the chapter on Sleep the author has written marginal numbers, from 1-6, though with what object does not appear. In the translation the numbers would be placed in the left hand margin as follows:

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*See corrections of Latin text.

n. 421 at l. 6, the number 5.

p. 282 at l. 11, the number 6.

n. 422 at l. 12, the number 1.

p. 283 at l. 10, the number 2.

n. 423 at l. 5, the number 2.

n. 423 at l. 5, the number 2.

p. 284 at l. 2, 16, 25, the number, 2.

n. 425 at l. 5, the number 2.

n. 426 at l. 2, the number 2.

p. 285 at l. 4, 8, the number 2.

n. 427 at l. 8, the number 3.

n. 428 at l. 4, the number 4.

n. 429 at l. 3, the number 3.

p. 286 at l. 13, the number 3

n. 430 at l. 4, the number 5.

n. 430 at l. 9, the number 2.

n. 430 at l. 11, the number 3.

p. 287 at l. 7, the number 2.

n. 432 at l. 3, the number 2.

p. 300, l. 1, 2, *for* as when a troop has been raised to which the gate is opened, so it rushes on *read* "In gathered troop it rushes forth from every opened gate." [Virg. Aen. I. 82-3.]

p. 303, l. 25, *for* SPASMS *read* SPASM.

p. 306, l. 2, *for* "MELANCHOLIES" *read* "MELANCHOLY."

p. 328, l. 6, *for* 417 *read* 517.

n. 522, l. 12, *for* variey *read* variety.

p. 340, first footnote, *add words* cf. 1 E. A. K., 563, *2 ib.* 27.

p. 343, l. 30, *for* analagous *read* analogous.

p. 344, *After* chapter xii *add the heading*, vertigo and swoons..

p. 348, first footnote, *for* taties *read* toties.

CORRECTIONS OF LATIN TEXT.

Note.—The following corrections (which do not include corrections of references to the author's works) have been compared by Mr. Alfred H. Stroh with the original manuscript. Those marked with an asterisk are in agreement with the manuscript; the others are corrections of the author's text.

n. 84, l. 14, *for* at *read* et.*

n. 84, l. 21, *for* at *read* et.

n. 94, l. 8, *for* semicircular *I would read* medullare, *as in Vieussens; see n.* 17.

p. 30, l. 5, *for* cortex *read* cortex [observata], *as in Malpighi, see n.* 20.

p. 31, l. 8, *for* quod *read* [confirmant] quod.

p. 32, l. 4, *for* utique *read* itaque; *see n.* 20.

p. 32, l. 7, *for* penetrare *read* penetrant; *see n.* 20.

p. 32, l. 9, *for* para *read* pars [sanguinis]; *see n.* 21.

p. 32, l. ult., *for* animalium *read* animalium [corporibus]; *as in Leeuwenhoek; see n.* 36.

p. 33, l. ult., *for* ut *read* ut [Aristotelis] *as in Bartholin; see n.* 12.

p. 35, l. 1, *for* ABCDEF *read* BCDEF; *see n.* 36.

p. 35, l. 2, *for* EF *read* GF; *see n.* 36.

p. 35, l. 6, *for* quas *read* quæ.

p. 35, l. 12, *for* earum *read* eorum.*

p. 35, l. 35, *for* BC *read* BG; *see n.* 37.

p. 38, l. 2, ult., *for* Malpighius *read* Vieussens.

p. 39, l. 3, *for* efforment *read* efforment. [Et. Clar. Malpighius].

p. 46, l. 15-6, *for* et motorias ut ad musculos *read* ad motorias ut musculos *as in Bartholin, see n.* 12.

p. 47, l. 1, *for* tilissimum *read* subtilissimum.*

p. 47, l. 15, *for* igne *read* igne [et].

p. 48, l. 12, *for* expositi *read* expositam, *as in Boerhaave, see n.* 49.

n. 173, l. 5, *for* GH, DI, OK *read* FG, DI, CK *as in Leeuwenhoek, see n.* 36.

p. 72, l. 16, *for* 18 *read* 13.

n. 200, l. 26, *for* premuntur *read* premuntur [et sumunt perfectam et rotundam figuram]; *see loc. cit., n.* 200.

p. 97, l. 2 ult., *for* ranæ *read* aranæ; *see loc. cit., n.* 200.

n. 204, l. 9, *for* ranæ *read* aranæ.

n. 206, l. 6, *for* animat *read* animat [patet].

n. 209, l. 13, *for* ramosis *read* nervosis, *as in Bartholin, see n.* 13.

n. 222, l. 11, *for* quæ *read* quæ diximus, *as in Leeuwenhoek, see* n. 41. ?

n. 222, l. 12, Tab. v, fig. 3, is perhaps a mistake for Tab. v, fig. 1, which is the figure described in the paragraph referred to, n. 41. Figs. 1 and 3 are figs. 16 and 18 in the present translation. The author's text makes no other reference to figure 3, nor to the matter contained in n. 43 where the figure is explained. We have supplied this paragraph solely on the basis of the present reference.

n. 237, l. 18, *for* tendineis *read* tenuioribus, *as in Lancisi, see n.* 16.

n. 237, l. 21, *for* contiguæ *read* continuæ, *see n.* 16.

n. 237, l. 22, *for* tunicæ *read* tunicæ denudatum, *see n.* 16.

n. 238, l. 8, *for* membranam *read* membranas, *see n.* 16.

p. 112, l. 16, *for* offendi *read* ostendi,* *as in Leeuwenhoek; see n.* 33.

p. 112, l. 2 ult., *for* Ex *read* Et, *see n.* 42.

p. 112, l. 1 ult., *for* expansiones *read* extensiones, *see n.* 42.

n. 263, l. 1, *for* superior *read* superior.*

p. 130, l. 1, *for* Metaph. *read* Sap. Div. sec. Aegypt.

p. 130, l. 3, *for* similter *read* similiter.*

p. 130, l. 11, *for* iv *read* iii.

p. 130, l. 19, *for* 529 *read* 592 (*should be* 591).

p. 132, l. 4, *for* 441 *read* 991.

p. 132, l. 6, *for* Nat. Ausc. *read* Mundo.

p. 135, l. 15, *for Met.* . . . "Cogitatione *read* Sap. Div. sec. Aegypt. . . .
"[Prima materia], cogitatione.

p. 135, l. 17, *for* Met. *read* Sap. Div. sec. Aegypt.

p. 137, l. 8, *for* 150 *read* 144.

p. 137, l. 27, *for* vii *read* vi.

n. 307, l. 7, *for* vitam *read* vitam [vivit].

n. 330, l. 5, *for* expansiones *read* insertiones, *as in Winslow, loc. cit.*

n. 330, l. 15, cerebri *read* cerebelli.

n. 331, l. 2, *for* eminentiarum *read* eminentiarum faciei inferioris *as in Cd.* 65.
p. 830, 4 Ph. 208.

n. 331, l. 5, *for* eminentiarum *read* eminentiarum, externa vero *as in ditto.*

p. 164, l. 1, *for* duræ *read* piæ.

p. 176, l. 12, *for* activissimas *read* activissimos.*

n. 412, l. 1, *for* copiosam *read* copiosum.*

n. 417, l. 1, *for* arteriæ carotides *read* arteria carotis.

n. 422, l. 9, *for* hemispheria *read* hemispheria, haec.

n. 431, l. 14, *for* inducat *read* inducunt.

n. 447, l. 2, *for* eruti *read with the Latin editor,* crudi.*

n. 450, l. 1, *for* epilepseos *read* catalepseos, *see n.* 458 .

n. 461, l. 15, *for* quo *read* qua.

n. 477, l. 5, *for* quad *read* quod.*

n. 521, l. 6, *for* sed *read* seu.

n. 530, l. 2 ult., *for* sorbis *I would retain MS. reading* sorbibus.* *This word is rejected by the Latin editor as being "altogether spurious," though he points out that the author uses it, in the same connection as here, in his* De Spir. Anim. cap. xii. (Opusc. Phil. p. 46.) Sorbus *means the fruit of the service-tree, and this meaning is so highly improbable in the present connection, as to be practically out of the question. As to sorbibus being spurious Latin, we note, 1. That it is quite certain that our author uses this word; and 2. that, while the word does not occur in the Latin classics, yet it is formed according to good Latin usage, viz.,* sorbes (*drink*) *from* sorbere (*to drink*), *just like* sordes (*filth*) *from sordere* (*to be filthy*). *The Latin editor was inclined to substitute the reading* sordibus, *but there is no necessity to depart from the plain reading of the MS.*

n. 538, l. 15, *for* inferiorem *read* superiorem, *as in* 1 *E. A. K.* 563, 2 *ib.* 27.

n. 550, l. 4, *for* toties *I would read* totius.

n. 560, l. 17, *for* exilibus *read* exitibus.*

n. 561, l. 15, *for* officitur *read* afficitur.*

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